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EVALUATION OF SINTERED METAL BRAKES FOR THE BAK-12 AIRCRAFT ARRESTING SYSTEM

ALEX V. WOLFE, 1st LIEUTENANT, USAF

MAURICE E. PETERS

TECHNICAL REPORT SEG-TR-67-53

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DEPUTY FOR ENGINEERING
AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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FOREWORD

This report was initiated by the Equipment Development Branch (SEMHD), Delivery and Retrieval Division, Directorate of Crew and AGE Subsystems Engineering of the Systems Engineering Group, Wright-Patterson Air Force Base, Ohio. This organization and the Air Force Flight Dynamics Laboratory (FDFM) monitored the test program. Lt. Alex V. Wolfe (SEMHD) was the officer in charge of the tests and Mr. Maurice E. Peters (FDFM) was the test engineer. The Deputy of Limited War (ASJT) of the Aeronautical Systems Division provided the test authority. The effort was conducted under Project 1559, "Limited/SAW Test and Evaluation."

The tests were conducted in the Landing Gear Test Facility of the Air Force Flight Dynamics Laboratory at Wright-Patterson AFB, Ohio, between 23 January 1967 and 6 March 1967. This report was submitted by the authors November 1967.

The E.W. Bliss Company loaned the sintered metal brakes to the Air Force for the tests and provided technical assistance, both at no cost to the Government.

This technical report has been reviewed and is approved.

W. P. Shepardson

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ABSTRACT

This report presents the results of a comparison test between a conventional B-52 disk brake and a newly developed sintered metal brake. The conventional B-52 brake, with cerametallic linings, is currently used on the B-52 aircraft and on the BAK-9 and BAK-12 aircraft arresting systems. The newly developed brake has sintered metal brake linings and is designed for the same applications as the conventional brake.

The objective of the test program was to compare the useful life and operating characteristics of the conventional brake with that of the sintered metal brake under conditions of simulated arrestments. The laboratory controlled conditions simulated a BAK-12 arrestment of a 35,000-pound aircraft at a speed of 150 knots.

The conventional brake yielded a useful life of 166 arrestments and the sintered metal brake had a life of 427 arrestments. The coefficients of friction for both brakes remained relatively constant throughout the test program.

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SECTION I

INTRODUCTION

A test program was initiated to compare the useful life and operational characteristics of a conventional B-52 disk brake with those of a newly developed, sintered metal brake when used on the BAK-12 arresting system. The conventional brake was made by the Bendix Corporation and the newly developed brake was made by the E.W. Bliss Company. Currently, the conventional brake is used on the B-52 aircraft and on the BAK-9 and BAK-12 arresting systems. The newly designed brake was developed for the same applications as the conventional brake. The general configuration for both brakes is shown in Figure 1. The BAK-12 portable arresting system is shown in Figure 2.

The Bendix disk brake utilizes cerametallic linings. It consists of four key-driven segmented steel rotors, three cerametallic stators, a cerametallic backing plate, a cerametallic pressure plate, and the piston or actuator housing. Figures 3 through 5 show the brake prior to use.

The E.W. Bliss Company has developed a sintered metal brake which consists of four key-driven solid rotors, three stators, a backing plate, and a pressure plate. See Figures 6 through 8. The wear pads (Figure 8) are riveted to a stator base plate, and the sintered brake lining material is bonded to the rotors. The Bliss brake can be assembled into the original B-52 housing without additional modifications.

The BAK-12 aircraft arrestor, manufactured by the E.W. Bliss Company, uses four B-52 brake assemblies in the two energy absorbing machines (Figure 1). One absorber is located on

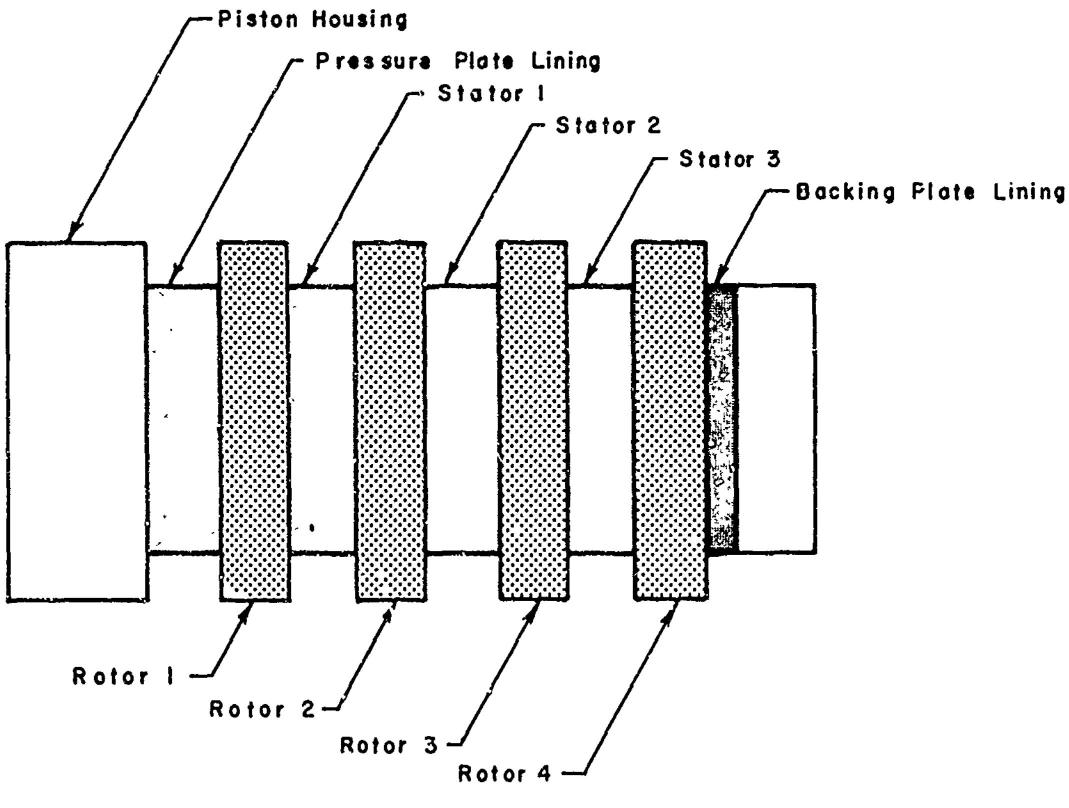


Figure 1. Brake Assemblies

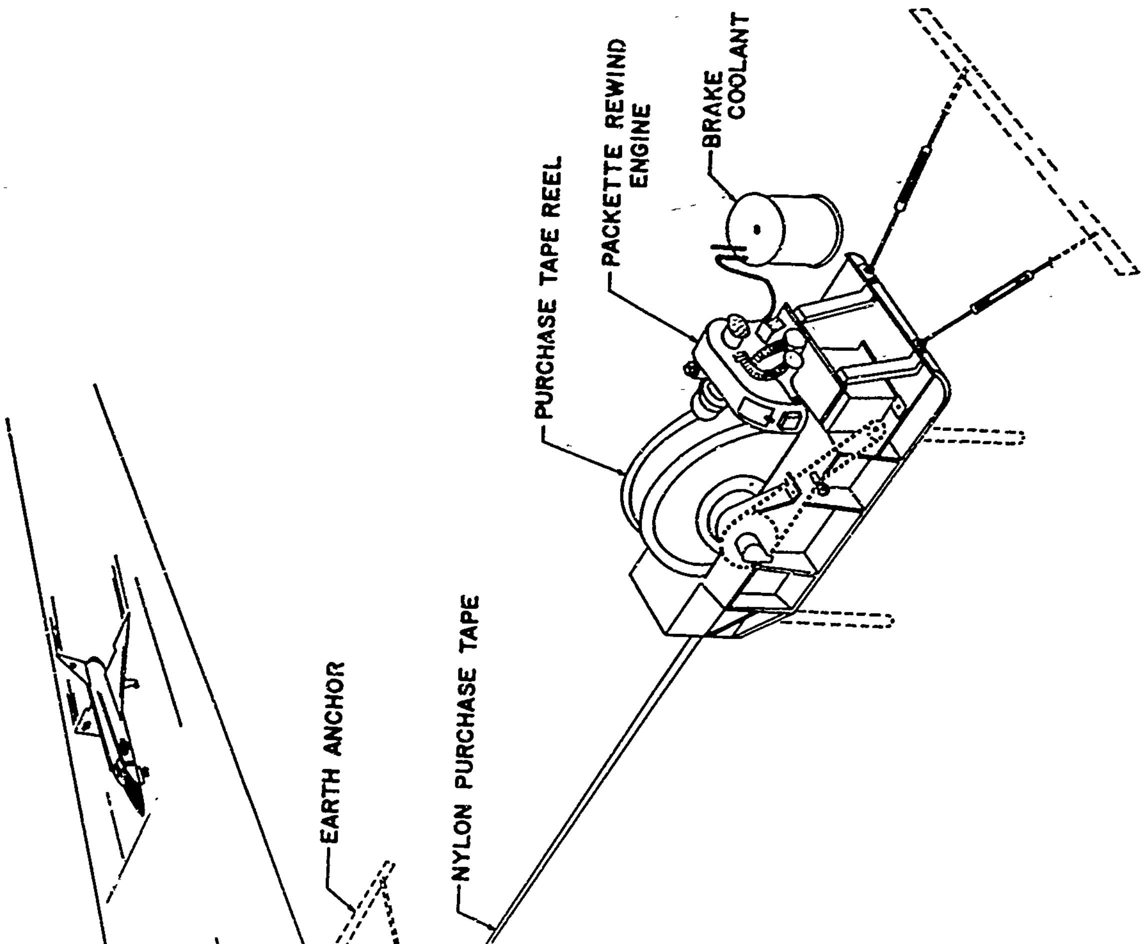


Figure 2. BAK-12 Portable Arresting System

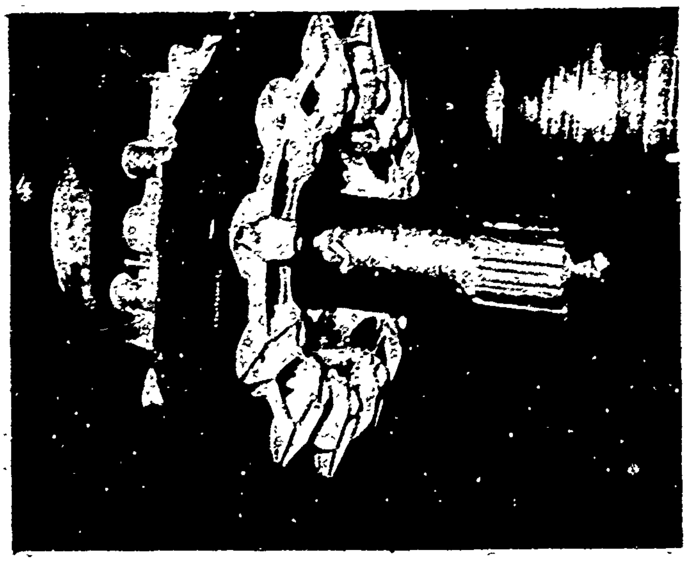


Figure 3. Bendix Brake Mounted on B-52 Test Axle

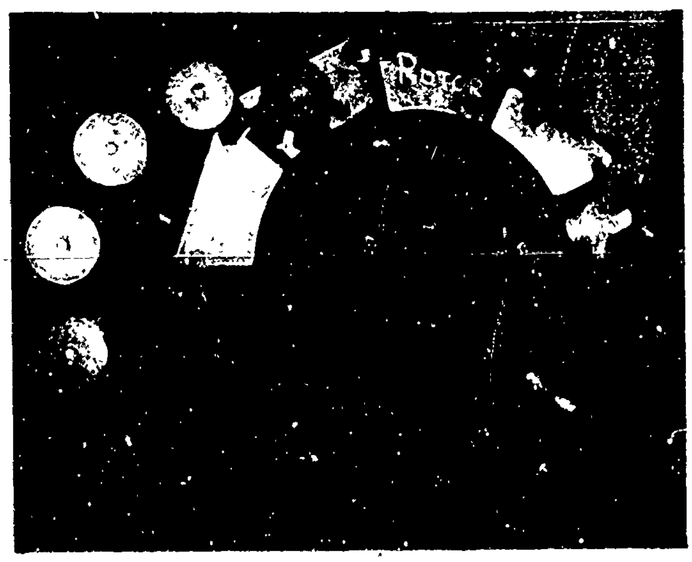


Figure 4. Bendix Rotor and Stator

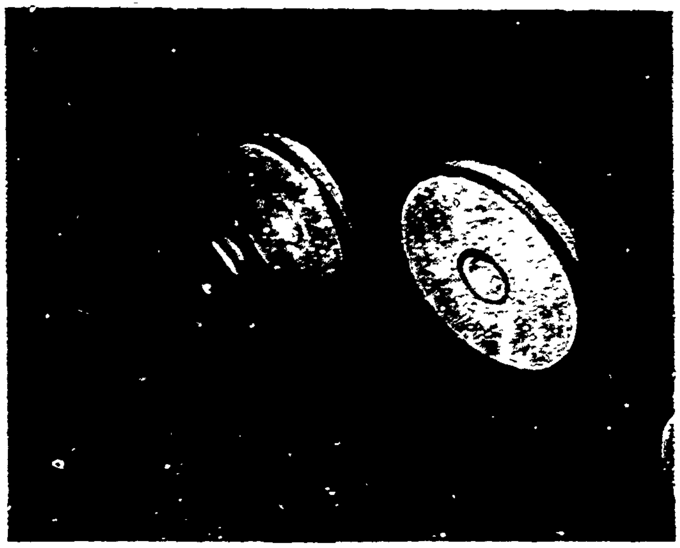


Figure 5. Cerametallic Lining Embodied in Metal Retaining Cup and Mounted on Stator

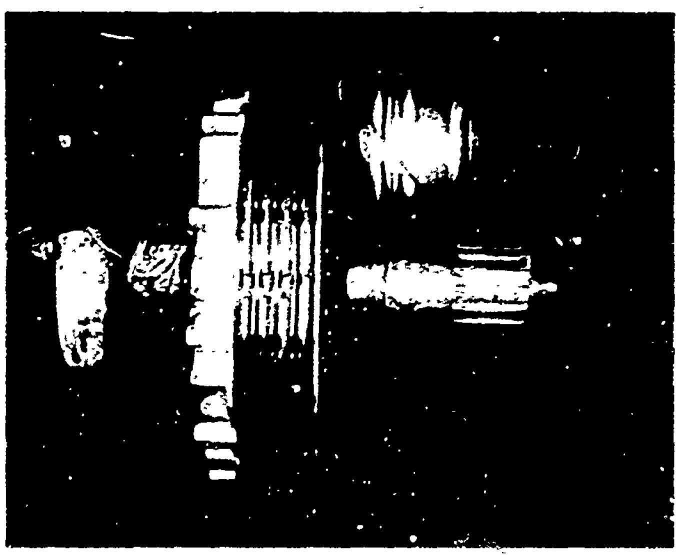


Figure 6. Bliss Brake Mounted on B-52 Test Axle

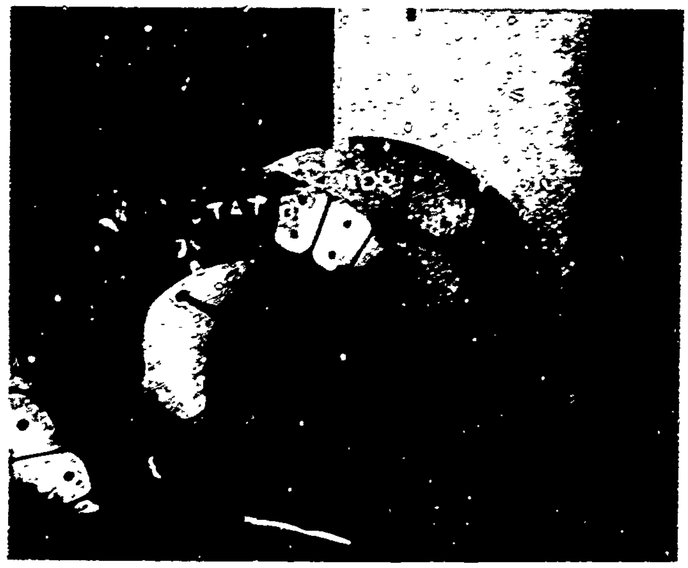


Figure 7. Bliss Rotor and Stator

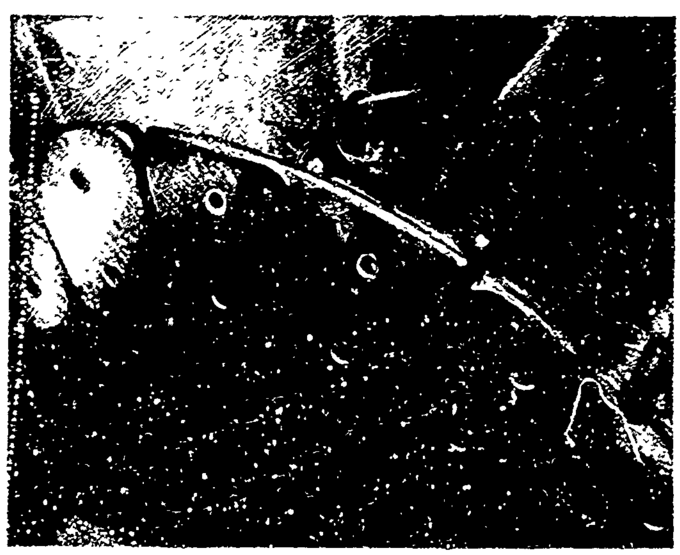


Figure 8. Bliss Riveted Wear Pads on Stator

each side of the runway and the absorbers are coupled together by a single steel cable and nylon purchase tapes. The purchase tape is wrapped on a storage reel which is splined to a shaft. Two B-52 brakes are mounted on a bearing block supporting the shaft, one on each side of the storage reel. As an aircraft engages the cable, nylon tape is pulled out and the brakes absorb the energy of the moving aircraft.

The 84-inch diameter inertia brake test dynamometer of the Landing Gear Test Facility in the Air Force Flight Dynamics Laboratory was used to conduct the tests.

SECTION II

TEST PROGRAM

The brake torque program was supplied by the E.W. Bliss Company. It consisted of two phases. The first phase was to conduct as many simulated arrestments on the Bendix brake as could be made. The test was to be terminated when the brakes were in a worn out condition or when erratic brake operation occurred. The second phase was to test the Bliss brake to the same conditions as the Bendix brake.

Simulated arrestments were conducted under laboratory-controlled conditions. These conditions were to simulate a 35,000-pound aircraft arrestment into the BAK-12 at 150 knots (34.8×10^6 ft-lbs energy). Since there are four brakes in the BAK-12 system and only one brake to be tested on the dynamometer, one-fourth of the total energy must be absorbed by one brake (8.7×10^6 ft-lbs).

SECTION III

DESCRIPTION AND OPERATION OF TEST EQUIPMENT

1. DESCRIPTION

The 84-inch diameter inertia brake dynamometer was selected for the test program because of its unique brake torque programming equipment and its adequate energy capacity.

The brake torque programmer is a closed servoloop operation consisting of a torque feedback signal, flywheel speed signal, brake pressure servovalve, and a function generator. The programmed torque (dependent variable) versus flywheel speed (independent variable) generates a command signal to the brake pressure servovalve. The servovalve then meters the pressure to the test brake as a function of the command signal to the torque feedback signal that the brake generates during an energy absorbing stop. The brake pressure is, therefore, a variable and is dependent upon speed and effective brake torque. The programmed speed versus torque is shown in Figure 9.

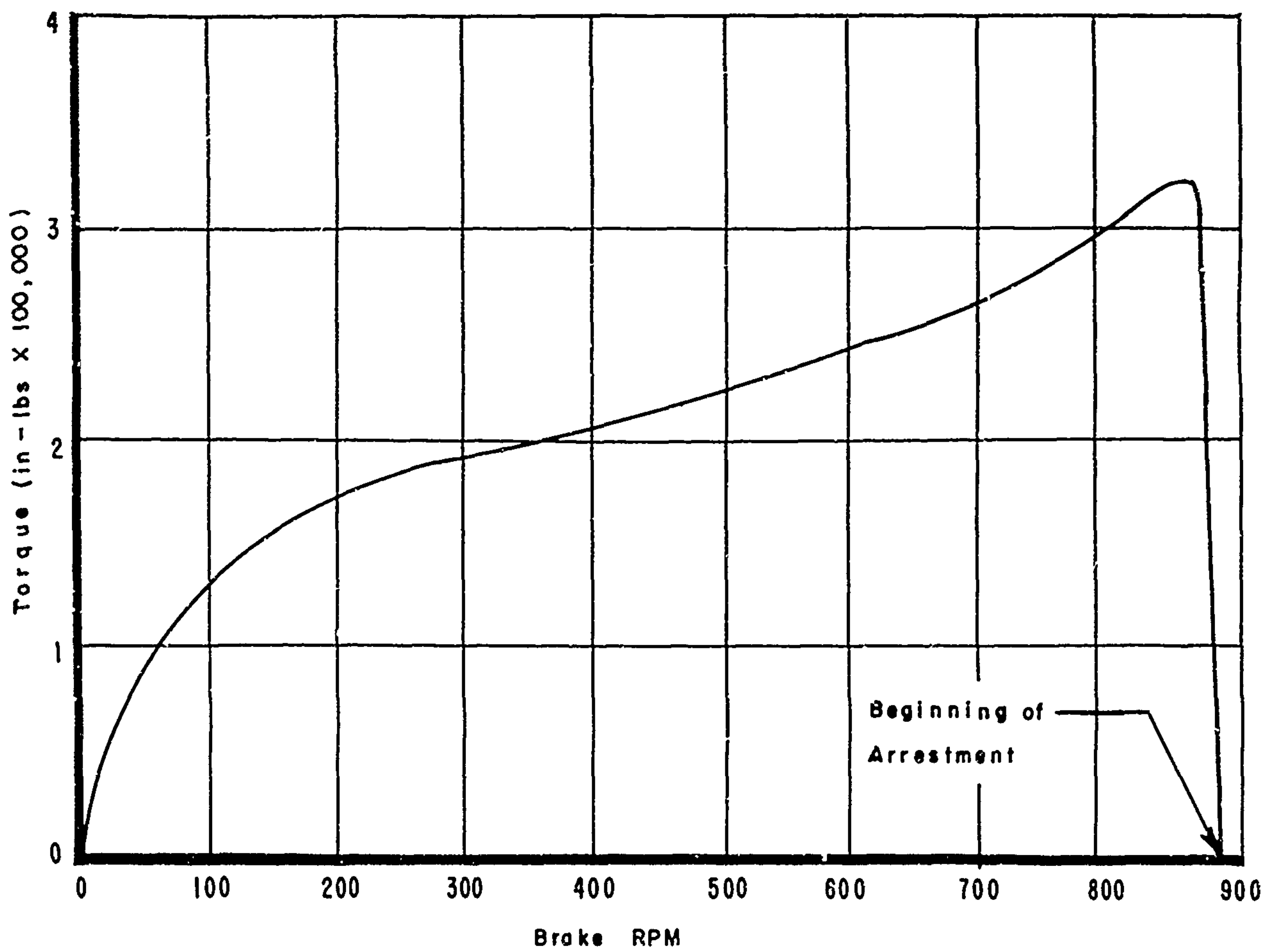


Figure 9. Programmed Torque Versus Brake RPM

A conventional B-52 wheel and tire had to be used to test the brakes on the inertia brake test dynamometer. Figure 10 shows a B-52 assembly loaded against the flywheel. The initial brake speed of the BAK-12 was met by the calculation of a rolling radius (RR) which was accomplished by calculating the ratio of the flywheel diameter to that of the RR of the tire and then equating the flywheel weight to the desired kinetic energy level. Calculations are shown in Appendix I.

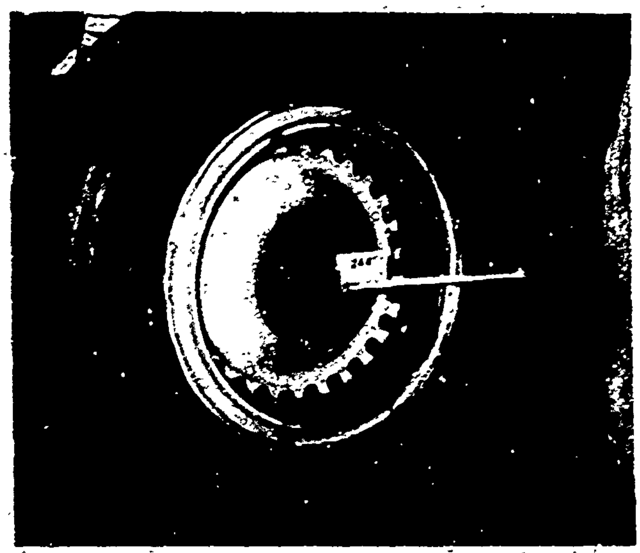


Figure 10. B-52 Wheel and Tire Assembly Landed Against Flywheel (Note RR 24.4 inches)

2. OPERATION

Once the dynamometer is programmed to the prescribed test conditions, the sequence of operations is semiautomatic. The operator presses a button which starts the operation. The flywheel is brought up to the prescribed landing speed of 512 RPM (equal to 882 brake RPM) at which time the wheel-brake and tire assembly is automatically landed against the rotating flywheel. When the prescribed load of 40,000 pounds and the RR of 24.4 inches are attained, the flywheel drive motor is automatically uncoupled from the DC drive source and the programmed brake torque automatically energizes the brake system. The braking system then brings the free spinning flywheel to a stop while following the prescribed program. During the braking cycle (simulated arrestment), the following parameters are recorded versus time: brake pressure, torque, flywheel speed, tire load and selected temperatures. An X-Y recorder records flywheel speed versus brake torque. Finally, a stop clock and flywheel revolution counter totalize the duration of the braking cycle.

SECTION IV

TEST RESULTS

1. BENDIX BRAKE 1

The first series of simulated arrestments, with the Bendix brake, were plagued with machine and operator difficulties; however, much was learned from this series of tests. In spite of the difficulties, the energy absorption per test run remained the same (8.7×10^6 ft-lbs). However, the rate at which the energy was absorbed deviated to a great extent from the programmed rate; therefore, a comparison with the Bliss brake performance was practically impossible. Higher torques were recorded during some of the tests due to excessive delay in the brake pressure application and air in the hydraulic system.

The brake was disassembled, inspected, and measured after 66 brake simulated arrestments. Figures 11 and 12 show the condition of the pressure plate lining which was the most severely worn lining, after 66 arrestments.

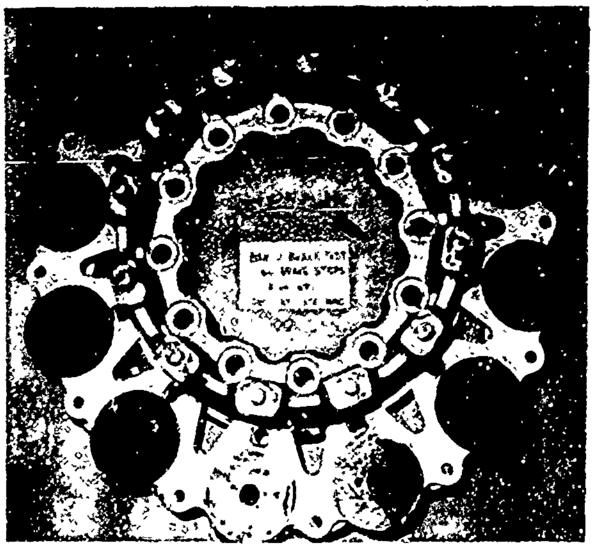


Figure 11. Pressure Plate Lining of Bendix Brake 1 After 66 Brake Arrestments

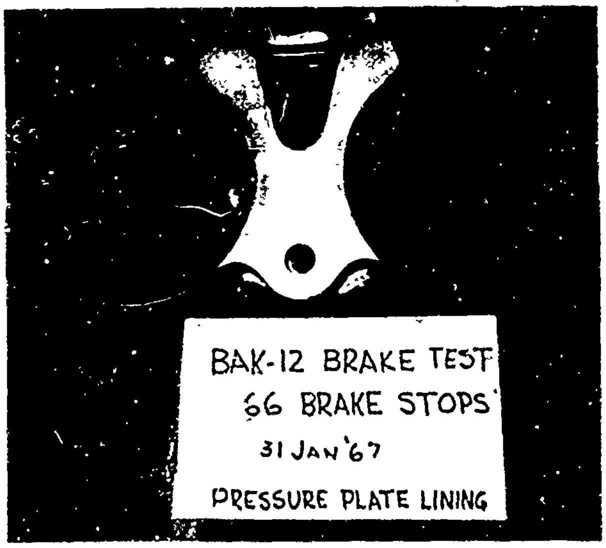


Figure 12. Most Heavily Damaged Brake Pad on the Pressure Plate

The preceding series of tests, conducted under laboratory controlled conditions, confirm the results obtained during field tests with actual aircraft during the first article BAK-12 evaluation. The report FTC-TDR-63-34 November 1963, Edwards AFB, page 34, clearly shows the same "breaking out" condition of the brake pads after 64 aircraft engagements.

The brake was reassembled and the tests were continued. A faulty thermocouple connection wrongly indicated that the brake was being adequately cooled in a 10-minute interval after each arrestment. Due to this faulty connection, arrestments 67 through 82 were conducted at intervals averaging 16 minutes. The 16-minute intervals varied from 5 minutes to 35 minutes. The time interval on the first 66 arrestments was 45 minutes. The brake performed satisfactorily during the short interval cycles.

After the error was discovered, the tests were continued through a total of 95 tests. Each test had a 45-minute cooling period. The tests were terminated at this point because of pulsating brake pressures.

The brake was disassembled and inspected again. Figures 13 and 14 show the condition of the pressure plate linings after 95 arrestments. It is interesting to note that the deterioration of the linings had not shown an appreciable increase from that of the linings which were taken after 66 arrestments (Figures 11 and 12) in spite of the high cycle rate of arrestments during Runs 67 through 82.

Figure 13. Pressure Plate Linings After 95 Simulated Arrestments

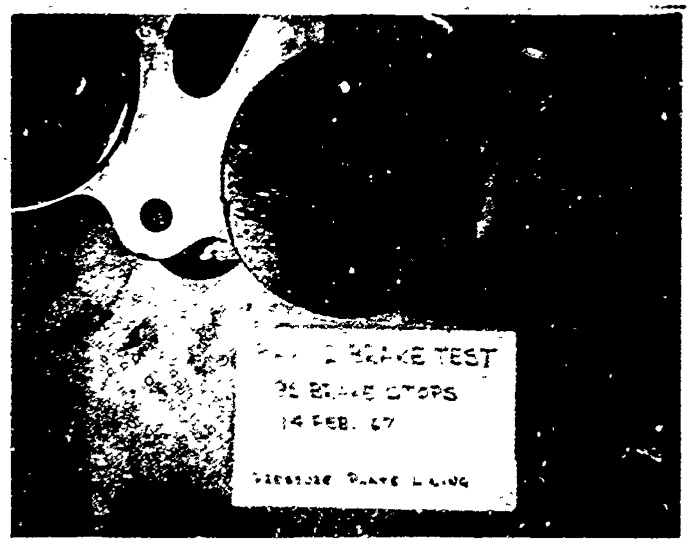


Figure 14. Most Heavily Damaged Lining on the Pressure Plate After 95 Arrestments (Same Lining as in Figure 11)

The brake pressures recorded throughout the 95 arrestments showed very little change in value or characteristic. A typical test as recorded by the X-Y recorder is shown in Figure 15. The brake pressure curve was superimposed on the curve after the arrestment.

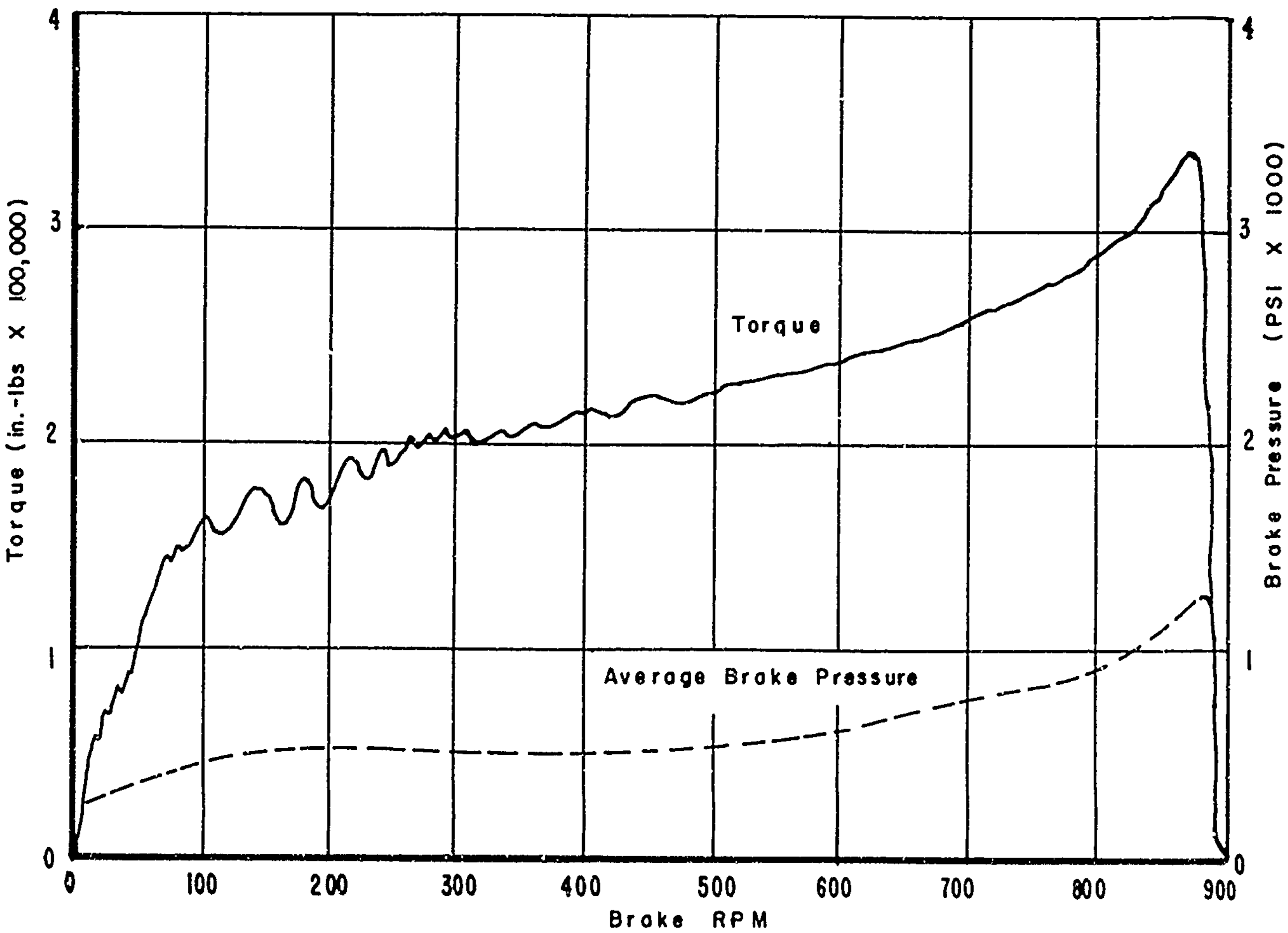


Figure 15. Typical Test Run on Bendix B-52 Brake

The results of the brake inspections after runs 66 and 95 are given in Tables I and II. These tables include the weights and measurements of the separate brake parts and also estimates of effective brake-lining area lost by damage to the cerametallic material during the arrestments. The estimates in Table I were made by several technicians working independently. There appears to be a discrepancy in the percent of area lost in the backing plate after 66 and 95 arrestments. This can be accounted for by noting that, when the material chipped out, the remaining material tended to "flow" into the vacant space due to the influence of high pressures and temperatures.

During the inspections after the 66th and 95th arrestments it was also noticed that many of the braking disks on the stators had become loose.

Figure 16 shows the results of a programmed constant torque test. This test was conducted to evaluate the brake effectiveness with heat buildup and has torque characteristics similar to those created during the braking of a B-52 aircraft. The brake pressure remained fairly constant throughout the test, indicating that the coefficient of friction of the lining remained constant throughout the heat buildup time. The constant torque test also provided a reference which was used to compare data received for a similar type arrestment for the Bliss brake.

TABLE I

ESTIMATED PERCENT OF EFFECTIVE LINING AREA LOST
DUE TO CHIPPED AND BROKEN OUT LINING MATERIAL

Lining	Percent after 66 arrestments	Percent after 95 arrestments
Pressure plate	15	18
Stator 1, rotor side 1	2	7
Stator 1, rotor side 2	1	3
Stator 2, rotor side 2	7	7
Stator 2, rotor side 3	1	2
Stator 3, rotor side 3	7	7
Stator 3, rotor side 4	1	1
Backing plate	5	4

TABLE II

WEIGHTS AND MEASUREMENTS FOR BENDIX BRAKE 1*

	Weights (pounds)			Measurements (inches)					
	New	After 66 tests	After 95 tests	New thickness		Thickness after 66 tests		Thickness after 95 tests	
				I.D.	O.D	I.D.	O.D.	I.D.	O.D.
Pressure plate lining	58 1/2	57 1/2	57 1/2	0.206	0.206	0.197	0.193	0.122	0.122
Backing plate lining	22 1/2	22	22	0.206	0.204	0.189	0.189	0.120	0.120
Stator 1	16	15	15	0.553	0.554	0.477	0.493	0.482	0.504
Stator 2	16	15	15	0.546	0.546	0.495	0.502	0.464	0.473
Stator 3	16	15	15	0.549	0.550	0.498	0.484	0.478	0.503
Rotor 1	24 1/2	24	24	0.367	0.370	0.363	0.366	0.358	0.368
Rotor 2	24 1/2	24	24	0.373	0.372	0.371	0.367	0.371	0.363
Rotor 3	24 1/2	24	24	0.371	0.372	0.369	0.368	0.368	0.367
Rotor 4	24 1/2	24	24	0.376	0.377	0.373	0.374	0.373	0.373

*See Figure 2 for schematic sketch of brake.

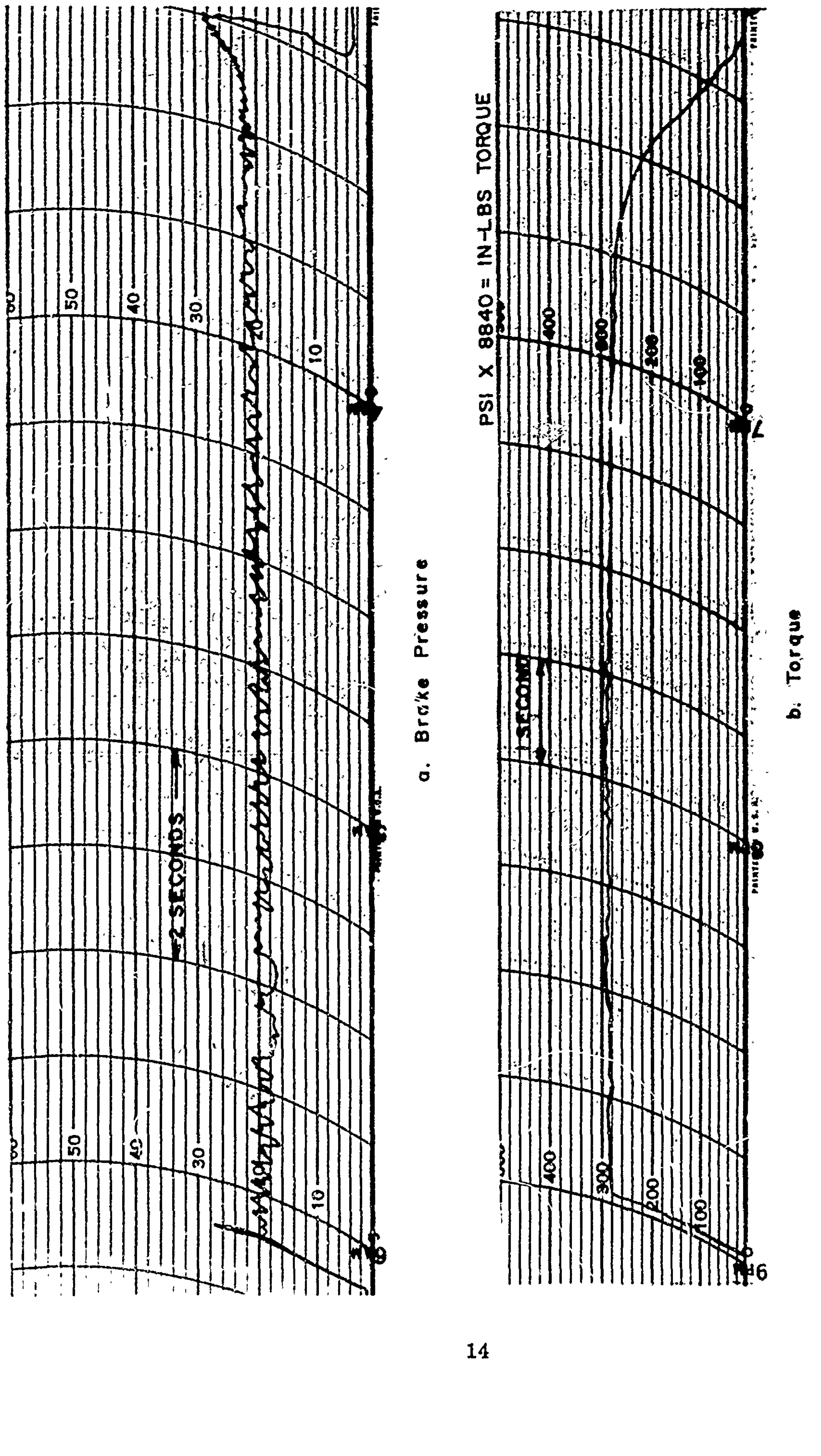


Figure 16. Constant Torque Data for Bendix Brake

The wear rate, which was determined from pin measurements at a brake pressure of 250 PSI, can be seen in Figure 17.

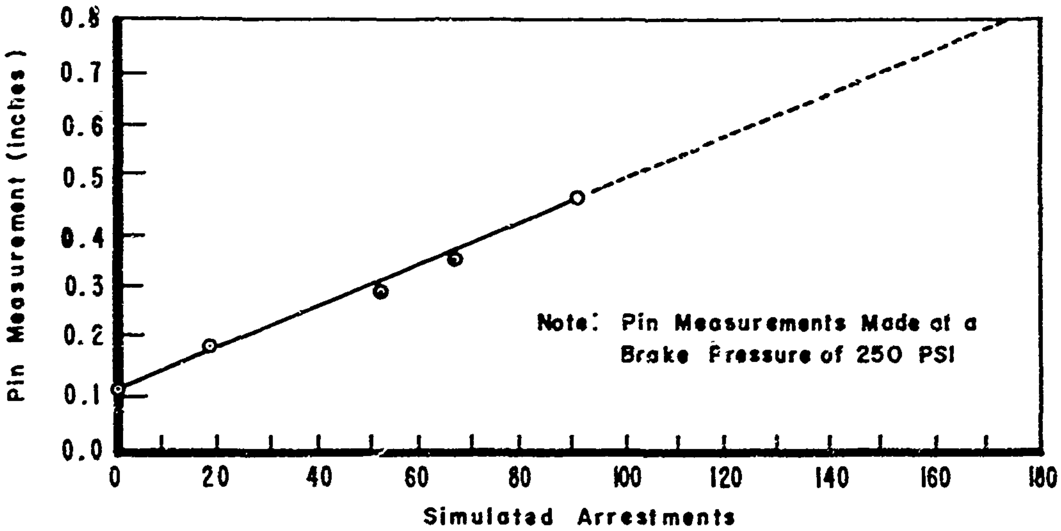


Figure 17. Wear Rate of Bendix Brake 1

2. BENDIX BRAKE 2

After termination of tests on the first Bendix brake, tests were begun on a second brake. The first 32 simulated arrestments were erratic, noisy, and excessive pulsations in the brake pressure recordings were indicated. The brake was disassembled and inspection revealed that the Number 3 rotor had a broken link and the Number 1 rotor was warped (see Figures 18 and 19). The wear pattern on Rotor 1 indicated that the segments were defective from the start of the test and were probably due to manufacturing deficiencies.

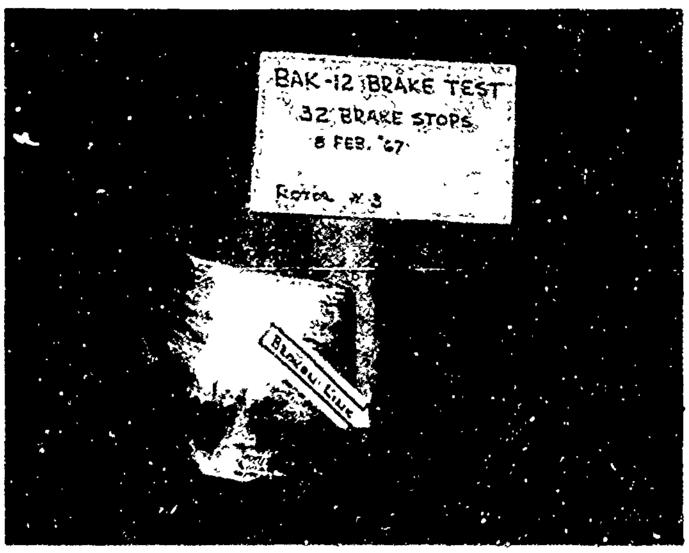


Figure 18. Rotor 3 and Missing Link

Figure 19. Wear Pattern of Rotor 1

The brake was reassembled, using Rotors 1 and 2 from the first Bendix brake to replace Rotors 1 and 3. Using worn rotors as replacement parts did not affect the brake operating characteristics because all the data duplicated the valid data from the first brake test.

This brake was not inspected at 66 stops because the information which could be obtained from such an inspection would duplicate the information obtained from the first brake. It was planned to disassemble the brake at 200 stops, but the program was terminated after 166 simulated arrestments. The test was terminated at this point because the specification for relining the brake limits the pressure plate travel to 23/32 of an inch (0.718 inch) and at 166 arrestments the measured travel pressure plate travel was 0.713 inch at a brake pressure of 250 PSI. The initial measurement was 0.109 inch. The average wear rate was 0.0036 inch per arrestment. See Figure 20 for a measure of wear rate throughout the brake life.

The brake was disassembled and weights and measurements were made (see Table III).

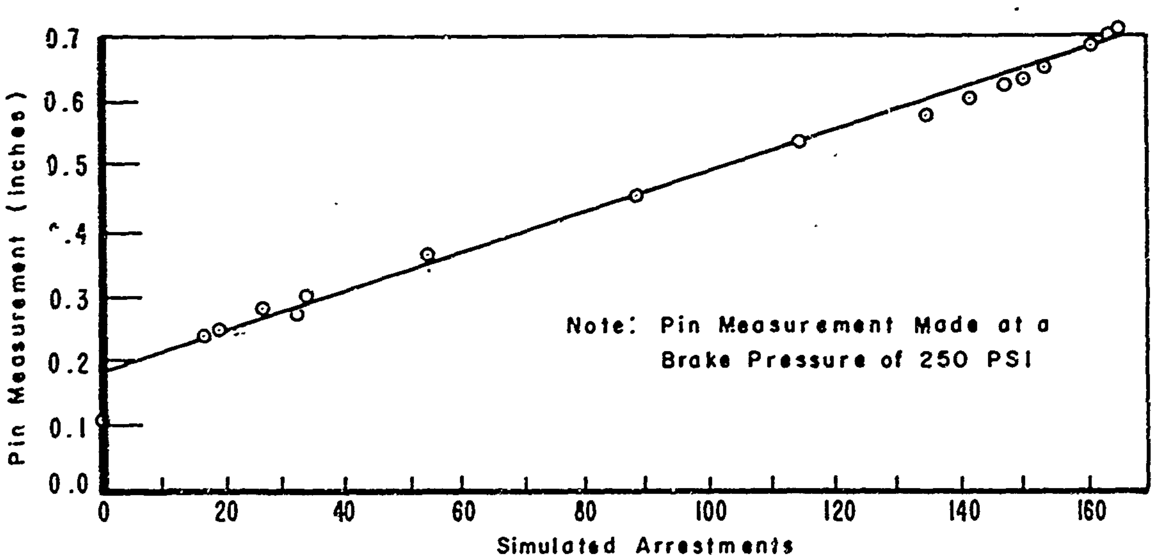


Figure 20. Wear Rate of Bendix Brake 2

TABLE III

WEIGHTS AND MEASUREMENTS FOR BENDIX BRAKE 2*

Lining	Weights (pounds)			Measurements (inches)					
				New thickness		Thickness after 32 tests		Thickness after 166 tests	
	New	After 32 tests	After 166 tests	I.D.	O.D.	I.D.	O.D.	I.D.	O.D.
Pressure plate lining	58-1/2	58	56	0.220	0.220	0.215	0.215	0.092	0.092
Backing plate lining	22-1/2	21	19	0.206	0.206	0.168	0.168	-	-
Stator 1	16	16	13-1/2	0.553	0.554	0.518	0.528	0.399	0.405
Stator 2	16	16	13-3/4	0.546	0.546	0.528	0.532	0.425	0.441
Stator 3	16	16	14	0.549	0.550	0.519	0.525	0.430	0.432
Rotor 1	24-1/2	24-1/4	23-1/4	0.358	0.368	0.369**	0.370**	0.359	0.360
Rotor 2	24-1/2	24-1/4	23-1/4	0.373	0.372	0.364	0.368	0.357	0.367
Rotor 3	24-1/2	24-1/4	23-1/4	0.371	0.363	0.371	0.371	0.369	0.361
Rotor 4	24-1/2	24	23-1/4	0.376	0.377	0.368**	0.371**	0.363	0.365

*See Figure 2 for schematic sketch of brake.

**No. 1 rotor, segments warped, No. 3 rotor, broken link
No. 1 and No. 3 rotors replaced with No. 1 and No. 2
Rotors from brake tests having 95 stops

Figures 21 through 24 show the condition of the linings at the conclusion of the test. The backing plate linings had the most amount of wear. Approximately 15% of the effective lining area was remaining (see Table IV).

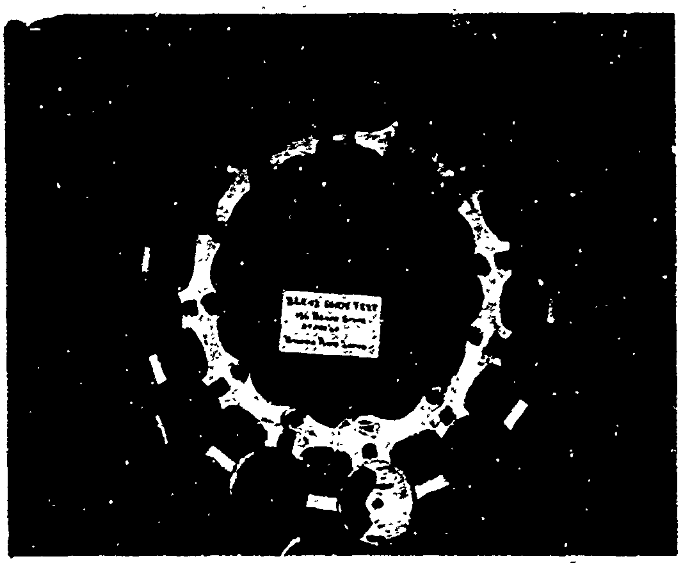


Figure 21. Backing Plate Lining After 166 Arrestments

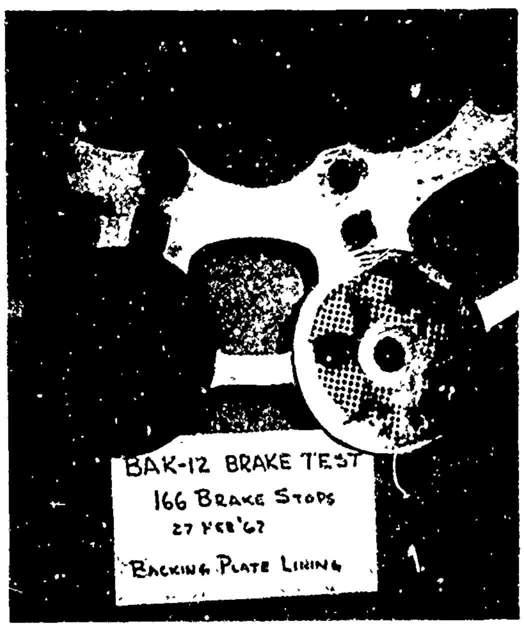


Figure 22. Closeup of Backing Plate Linings

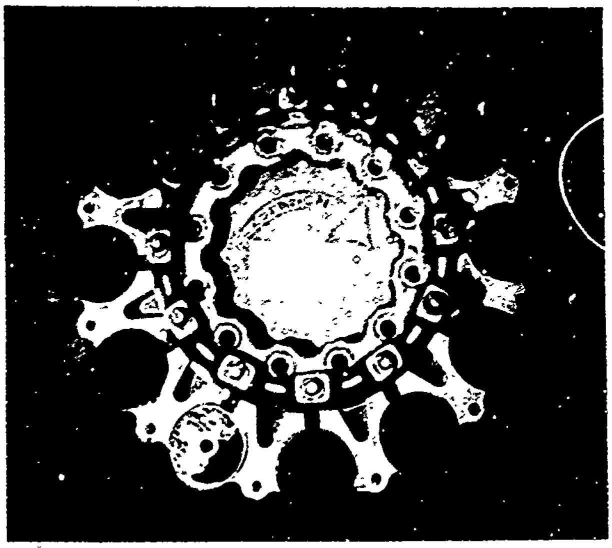


Figure 23. Pressure Plate Lining After 166 Arrestments

Figure 24. Closeup of Pressure Plate Lining

TABLE IV

ESTIMATED PERCENT OF EFFECTIVE LINING AREA LOST DUE TO CHIPPED OUT LINING

Lining		Percent after 166 arrestments
Pressure plate		17
Stator 1	Rotor side 1	20
Stator 1	Rotor side 2	40
Stator 2	Rotor side 2	12
Stator 2	Rotor side 3	25
Stator 3	Rotor side 3	20
Stator 3	Rotor side 4	12
Backing plate		85

The coefficient of friction throughout the brake life was plotted in Figure 25. The coefficient was determined from the output torque and brake pressure at a point 2 seconds after the arrestment began (see Appendix I-2). From past experience, the coefficient of friction is known to decrease with brake life; however, it only decreased up to 30 arrestments and then remained at a constant value. It appears that the coefficient decreased up to the point where chipping out of the brake lining began. After chipping begins, a steel rim is exposed and serves as a steel-on-steel brake and this type of brake has a constant coefficient of friction, but a steel-on-steel braking surface is not an adequate brake.

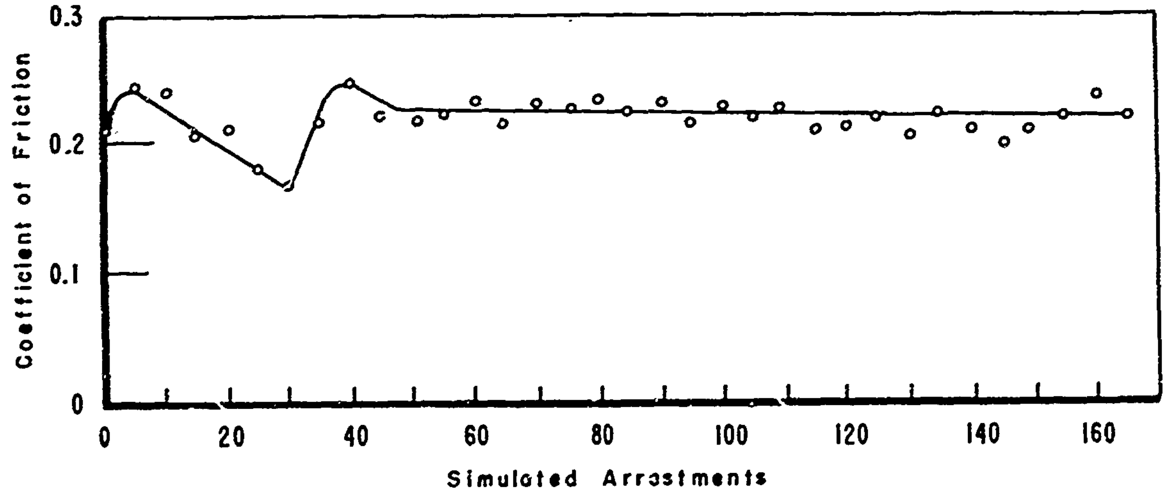


Figure 25. Coefficient of Friction for Bendix Brake 2

3. BLISS SINTERED METAL BRAKE

After completion of the Bendix brake tests, tests were begun on the E.W. Bliss Company sintered metal brake. The test program was identical to the one used for the Bendix brakes. After 62 and 200 simulated arrestments, the Bliss brake was disassembled for inspection of and comparison with the Bendix brakes.

The brake appeared to be in good condition after 62 simulated arrestments. The rotor linings had a good glaze and very few signs of chipping (see Figure 26). The wear pads on the stator showed signs of "dishing." "Dishing" can be defined as the turning up of the edges of the wear pads (see Figure 27). This effect is normal for wear pads that are retained as are the Bliss pads; that is, connected with two rivets at the center of the wear pad. The "dish" amounted to approximately 0.040 inch, which means that the wear pads will wear around their perimeter or outer edges (see Figures 27 and 28) more so than at the center.

During the first 62 simulated arrestments, temperatures were recorded from the four rotors through the use of thermocouples and slip rings. The peak temperature rise per arrestment was 400° ±10°F. This peak was reached within 30 seconds of the brake application. The thermocouples were placed in 1/16-inch diameter by 1-1/4-inch deep drilled holes in the outer edge of each rotor. The pressure plate and piston housing temperatures were also observed; the temperature rise on the pressure plate was 100° ±10°F and the rise on the housing was 10°F. An average of 45 minutes was required to cool the brake to 190° ±10°F which was the Bliss recommended maximum acceptable brake temperature prior to an arrestment. Seven thousand CFM of air at 70°F was directed across the brake well area as a means of cooling the brake assembly. The 45-minute cycle is required because of the brake confinement in the B-52 wheel.

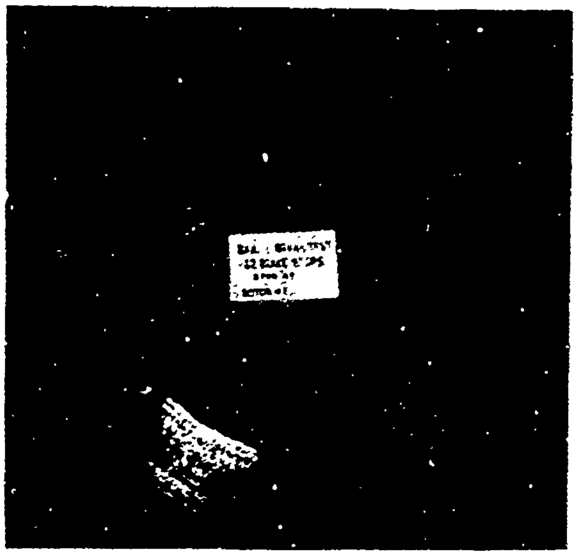


Figure 26. Bliss Rotor 1 After 62 Arrestments

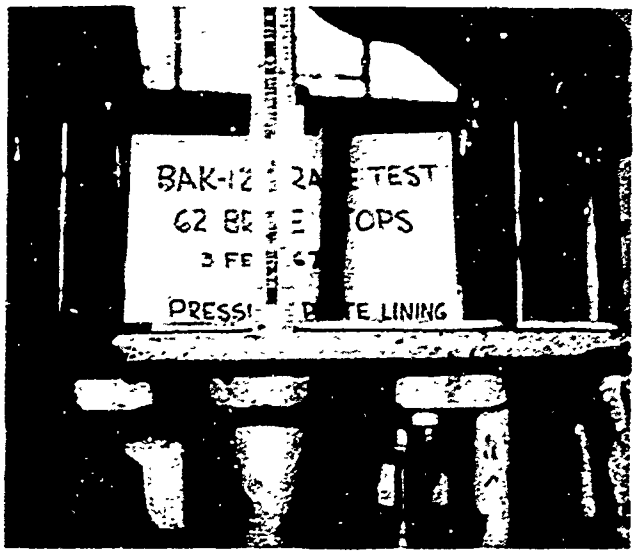


Figure 27. Dishing of Pressure Plate Wear Pad

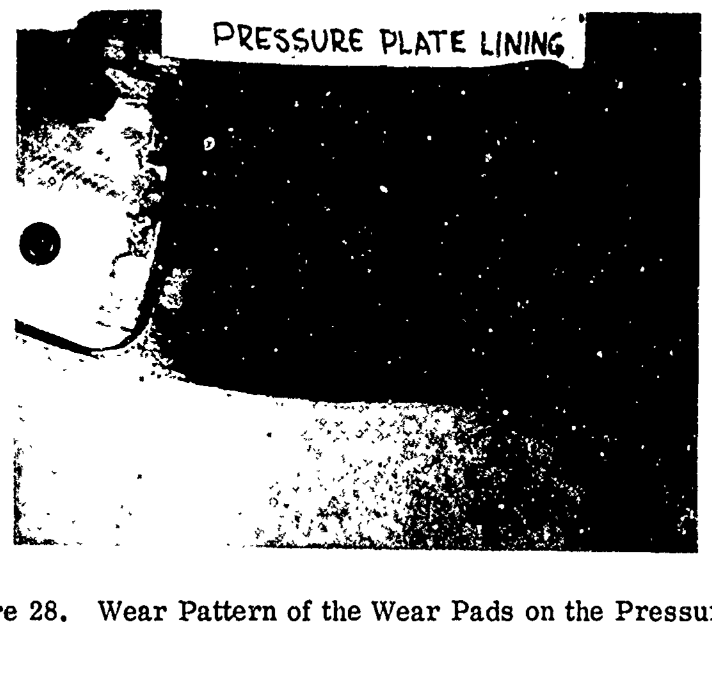


Figure 28. Wear Pattern of the Wear Pads on the Pressure Plate

A typical test, as recorded by the X-Y recorder, is shown in Figure 29. The brake pressure curve was superimposed after the test. A constant torque test was conducted to evaluate the brake effectiveness with heat build-up and has torque characteristics similar to those created during the braking of a B-52 aircraft. Figure 30 shows the results of this test. An analysis of the brake pressure curve indicates that the lining coefficient of friction increases with temperature rise. This constant torque test was at the same energy level (8.7 x 10^6 ft-lbs) as the other programmed variable torque stops.

After 200 simulated arrestments the brake was still in good condition with the exception of Rotor 4. This rotor was "dished" approximately 0.025 inch across the wear surface (from the outer diameter to the inner diameter). The linings still had good glaze, but some chipping was beginning to occur. Figures 31 and 32 show Rotors 1 and 4 in the most damaged area. Very few changes had occurred since the inspection at 62 stops.

The Bliss brake tests continued until the brake would not perform properly. The brake torque showed a marked decrease during test 428 and was further verified during test 429. Therefore, a total of 427 successful simulated arrestments were made on the Bliss brake. The pin measurement was 0.676 inch at a brake pressure of 250 PSI.

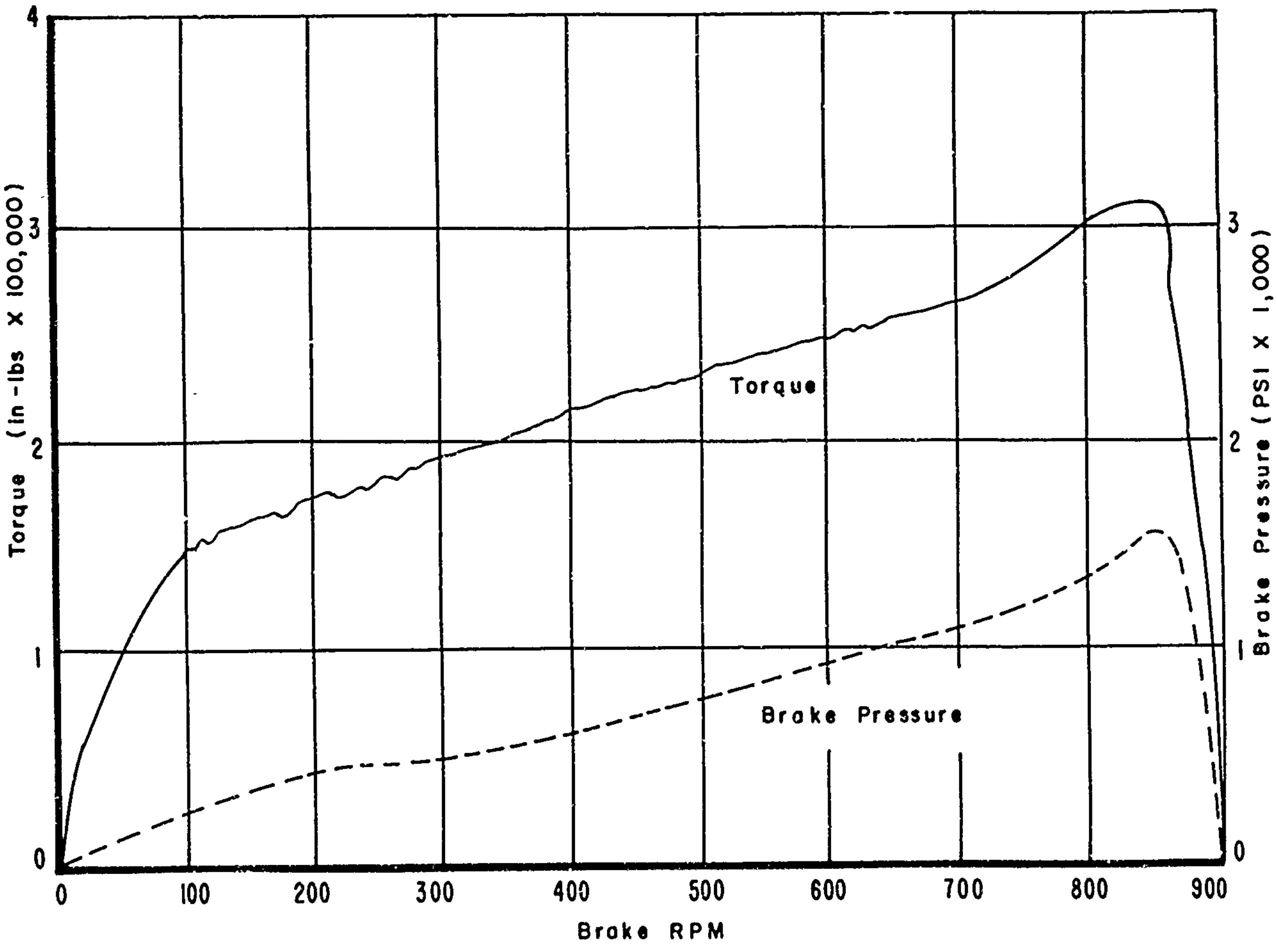
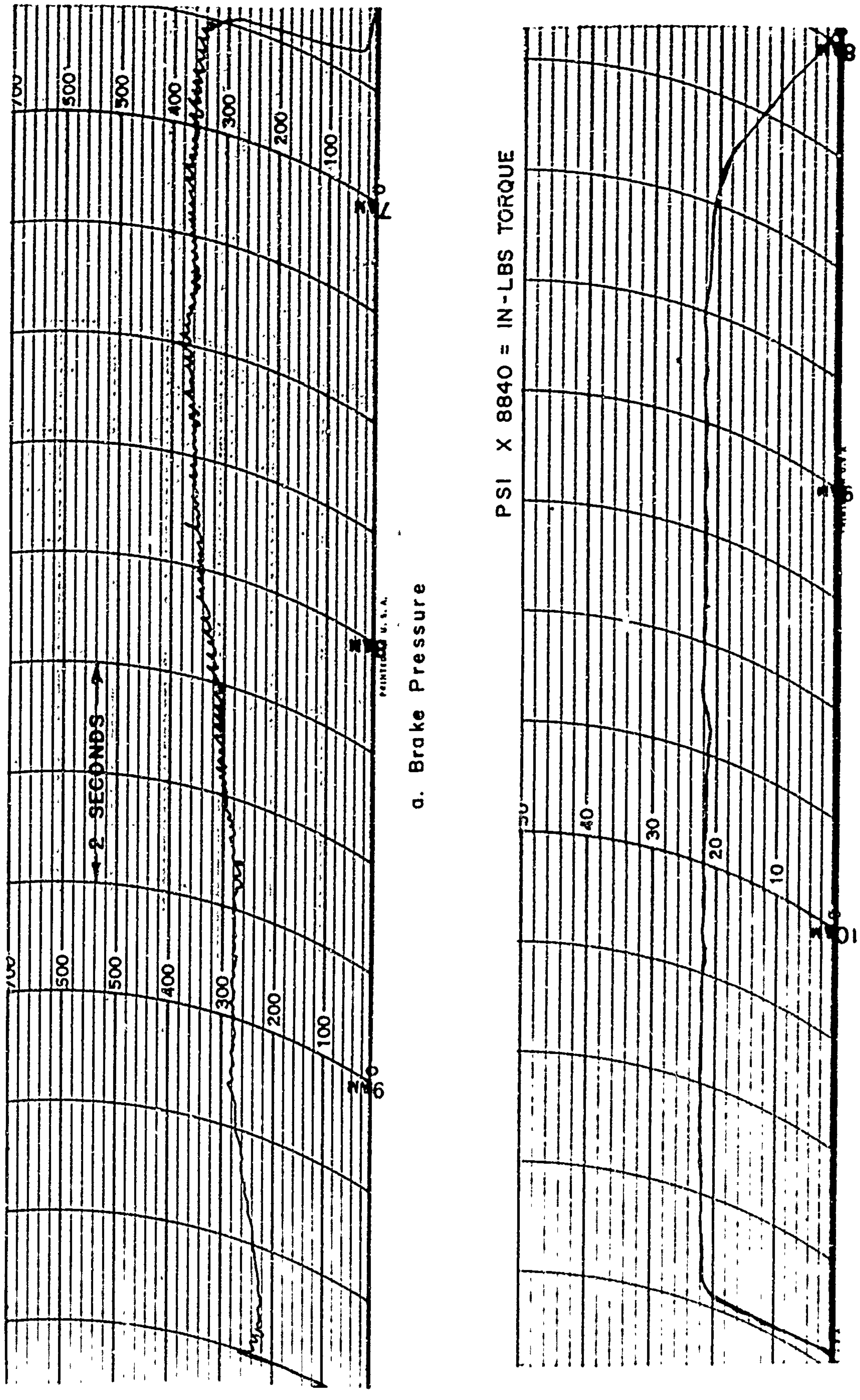


Figure 29. Typical Test Run on Bliss Brake



a. Brake Pressure

b. Torque

Figure 30. Constant Torque Data for Bliss Brake

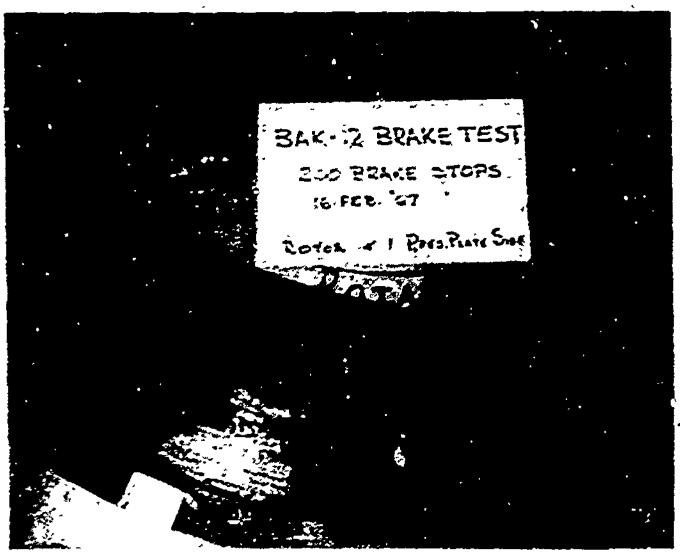


Figure 31. Bliss Rotor 1 Showing Chipped Area After 200 Arrestments

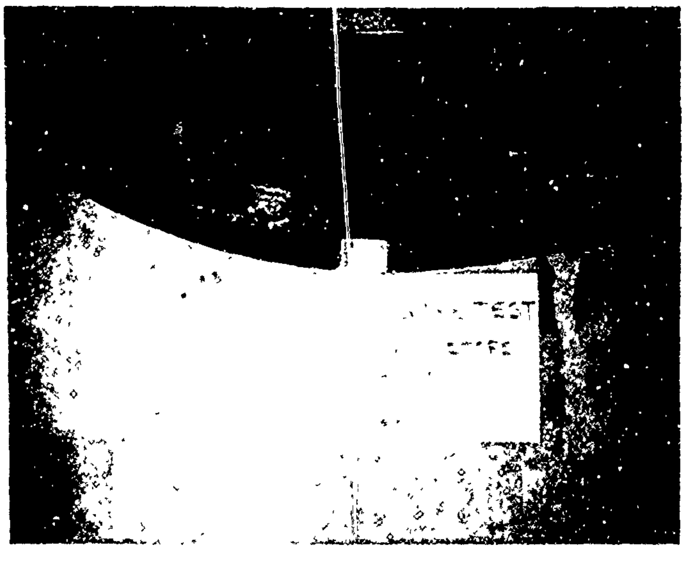


Figure 32. Bliss Rotor 4 Showing Chipped Area After 200 Arrestments

The brake was then disassembled for inspection and compared with the Bendix brake. Measurements as well as visual inspection revealed that the sintered material on the rotor was almost completely worn away (see Table V). There was much dust which had built up on the rotor, and, when it was cleaned off, it was evident that a few more successful arrestments could be made. However, the brake needed to be cleaned again within a few arrestments. Since this procedure was not practical, the test was not continued.

Chipping was very noticeable on the rotors, especially around the relief slots (see Figures 33 and 34).

The rotor had a pronounced glaze which indicates that the coefficient of friction remains constant. A flaking out of the wear pads caused a slight buildup of material on the rotor.

An investigation to discover any other brake deficiencies that might have occurred was conducted. The relief slots were examined for cracks and whether or not they had increased in width. Neither fault was found. Also the drive keys were studied to see if any noticeable battering or wear occurred. None was found.

Next the stators were examined. The most recognizable effect was the cracking of some of the wear pads (see Figure 35). This cracking was probably due to the "dishing" which causes the wear pads to wear mostly at the cutter edges. When these pads wear thin at the perimeter, they become structurally weak which in turn causes the pads to crack when brake pressure is applied.

"Dishing" of the wear pads was very pronounced. This effect resulted in the cracks on some of the wear pads as well as very little wear actually occurring at the center of the pads. The uneven wear and "dishing" can be seen in Figures 35 and 36, respectively.

The brake pad material tended to "flow" over the pad edges. A combination of high temperatures and high pressures caused this flowing.

The backing plate withstood "dishing", wear, and flaking better than any other brake component. On the other hand the pressure plate exhibited the worst conditions of "dishing", wear, and flaking (see Figures 37 and 38).

The results of the measurements are presented in Table V. Several of the stators have an increased thickness. This increase is due to the "dishing" of the wear pads. However, there was a considerable amount of wear as indicated by the decreases in stator weights.

Figure 39 indicates the wear rate for the Bliss brake. An average wear rate of 0.00125 inch per arrestment was indicated for the Bliss brake.

The coefficient of friction remained relatively constant throughout the brake life (see Figure 40). The fluctuations at the beginning of the test program were caused by the "breaking in" of the brake. The characteristic of a constant coefficient of friction is highly desirable because the braking torque will not erratically change from arrestment to arrestment.

TABLE V

WEIGHTS AND MEASUREMENTS FOR SINTERED METAL BRAKE*

Lining	Weights (pounds)			Measurements (inches)							
				New thickness		Thickness after 62 tests		Thickness after 200 tests		Thickness after 427 tests	
	New	After 200 tests	After 427 tests	I.D.	O.D.	I.D.	O.D.	I.D.	O.D.	I.D.	O.D.
Pressure plate lining	28 1/2	–	27 3/4	0.412	0.412	–	0.420	–	–	0.114	0.114
Backing plate lining	58.0**	–	57.5	–	–	–	–	–	–	–	–
Stator 1	26 1/4	26	25	0.450	0.450	0.457	0.456	0.460	0.453	0.457	0.464
Stator 2	26 1/4	26	25 1/2	0.451	0.451	0.457	0.456	0.465	0.457	0.442	0.439
Stator 3	26 1/2	26	25 1/2	0.451	0.451	0.457	0.458	0.459	0.459	0.464	0.466
Rotor 1	29	26 1/4	23 1/2	0.473	0.472	0.441	0.468	0.417	0.430	0.306	0.328
Rotor 2	29	26 1/4	23	0.474	0.472	0.446	0.455	0.407	0.430	0.341	0.315
Rotor 3	29	26 1/4	22 3/4	0.474	0.472	0.448	0.443	0.416	0.412	0.333	0.312
Rotor 4	31	26	22 1/2	0.471	0.469	0.445	0.440	0.427	0.390	0.334	0.318
Piston housing	30										
Total	313 1/2										

NOTE: Rotor thickness less lining = 0.313.

*See Figure 2 for schematic sketch of brake.
**Backing plate lining not measured because of housing configuration.

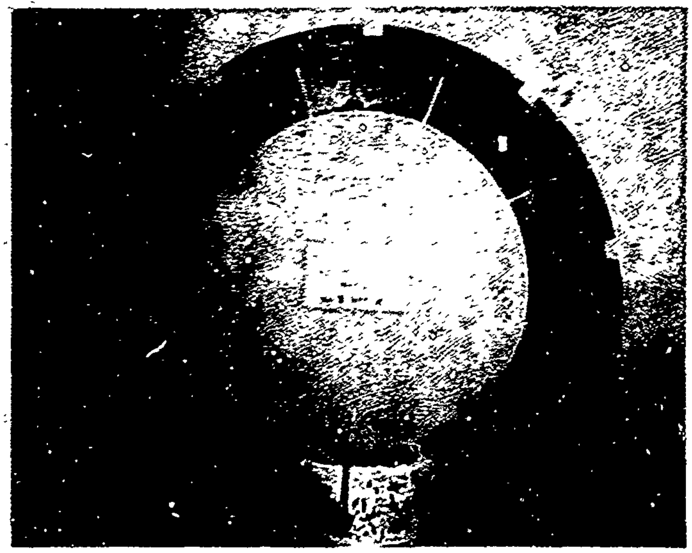


Figure 33. Bliss Rotor 3 Showing Chipped Area After 427 Arrestments

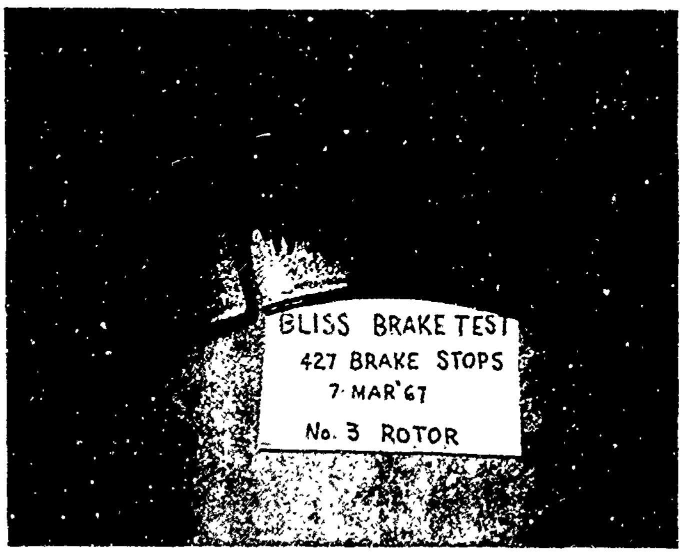


Figure 34. Closeup of Bliss Rotor 3 Showing Chipped Area After 427 Arrestments

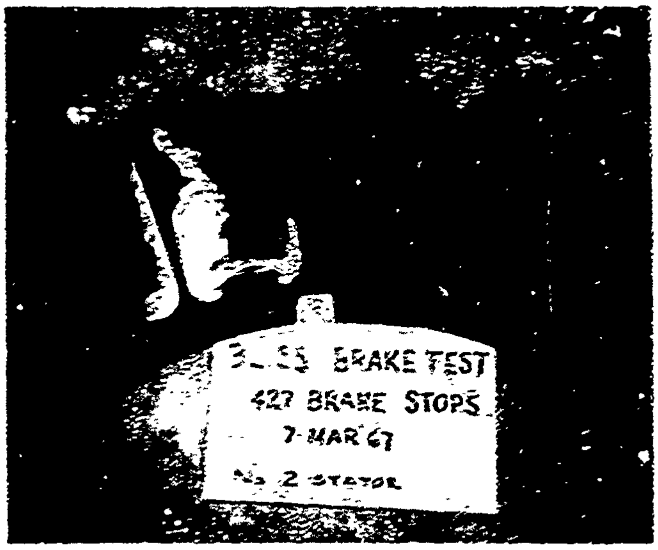


Figure 35. Bliss Rotor 2 Showing Cracks in Wear Pad After 427 Arrestments

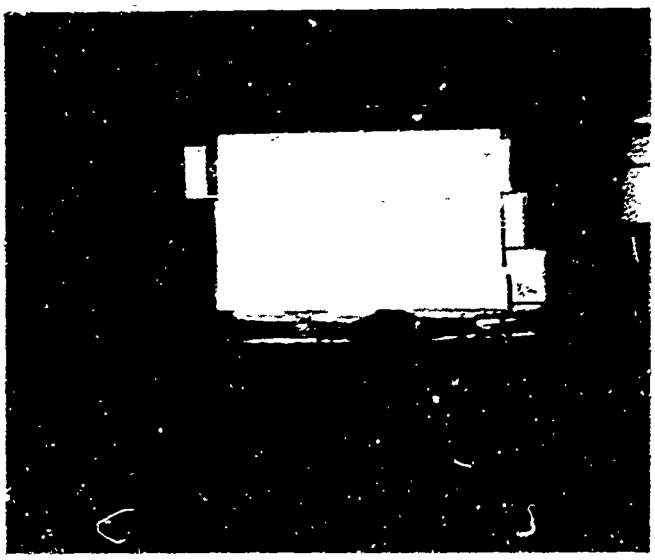


Figure 36. Dishing on Bliss Stator 1 After 427 Arrestments

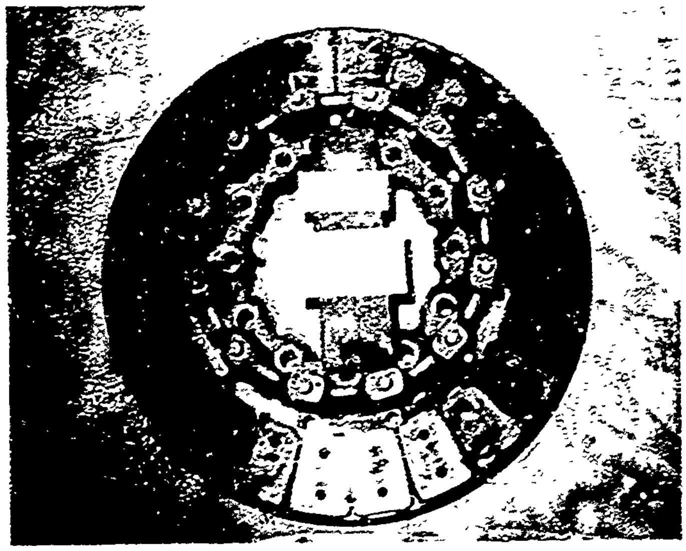


Figure 37. Bliss Pressure Plate After 427 Arrestments

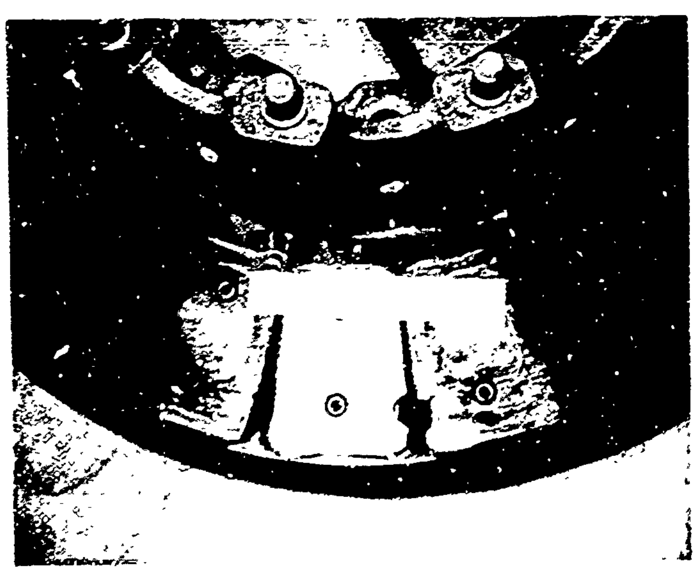


Figure 38. Closeup of Bliss Pressure Plate After 427 Arrestments

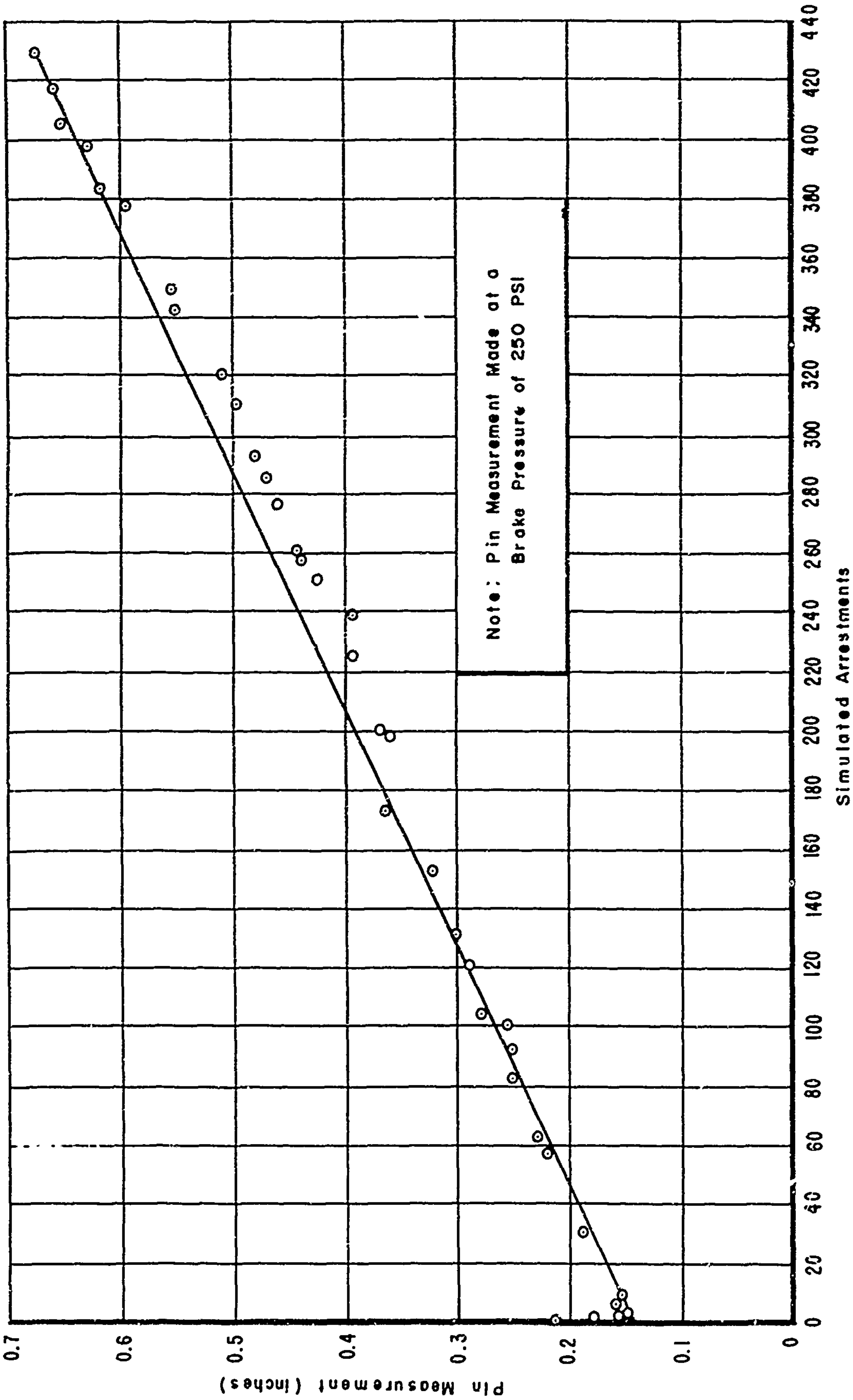


Figure 39. Wear Rate of Bliss Brake

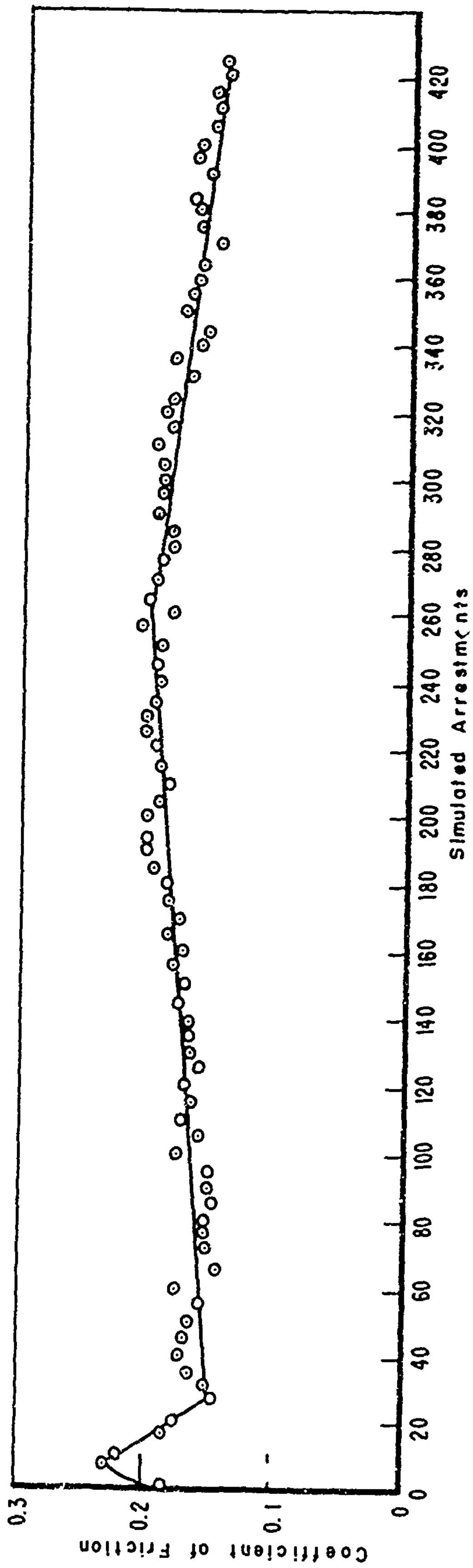


Figure 40. Coefficient of Friction for Sintered Metal Brake

SECTION V

CONCLUSIONS

The Bendix brake performed 166 simulated arrestments and the Bliss brake successfully completed 427 arrestments. The Bliss brake has a much smoother operation than the Bendix brake and is more suitable to the BAK-12 applications.

The "dishing" of the rotor and wear pads in the Bliss brake probably would not be as pronounced in actual application of the BAK-12 energy absorber, because brake pressure is maintained all the time so that tension can be maintained on the cable while the system is at standby.

A comparison of wear rates for the Bliss brake and the Bendix brake, illustrated in Figure 41, indicates that the sintered metal brake has 2 1/2 times as much life as the cerametallic brake.

The coefficient of friction for the Bendix brake decreases until the brake pucks begin chipping out and the Bliss brake coefficient remains relatively constant after the brake was broken in.

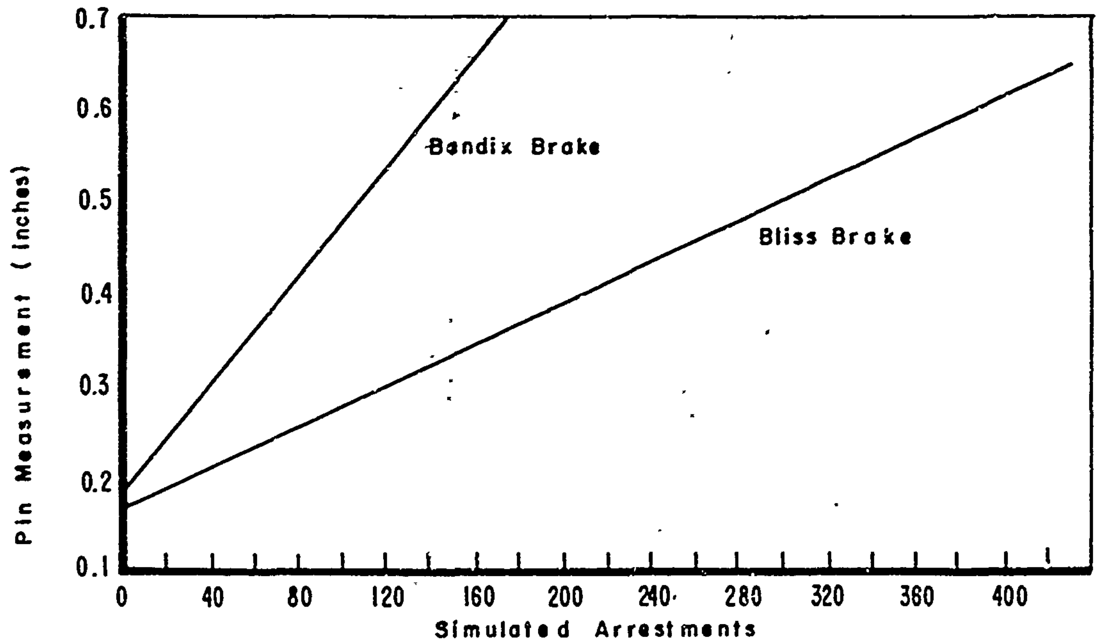


Figure 41. Wear Rate for Bendix and Bliss Brakes

SECTION VI

RECOMMENDATIONS

Based on efficiency, reliability, and life expectancy, the Bliss brake should be incorporated into the BAK-12 energy absorber.

The Bliss brake should be tested to the B-52 aircraft test conditions and evaluated for capability and reliability in this application. If the brake is tested in this application, the backing plate should be made of less weight and more flexible so that it can deflect with brake pressure. This should alleviate the tendency to "dish" and also decrease the uneven wear of the lining materials. However, the design of the backing plate must be carefully considered to insure a rigid construction. If the backing plate is allowed to bend under the normal load created by the brake pressure, the effective torque radius will change and affect brake performance. In turn the backing plate and adjacent rubbing surfaces will wear unevenly. This is evident from the severe damage to the backing plate of the Bendix brake.

The Bliss backing plate is of a much stiffer design to resist arresting gear application normal forces, which are much higher than B-52 application normal forces.

If it is decided to use the Bliss brake on the BAK-12, the brake linings should be replaced after a pin measurement 0.650 inch has been reached. This figure is somewhat lower than that which was actually measured in order to incorporate a factor of safety into the measurements.

APPENDIX I

CALCULATIONS FOR TEST PROGRAM

1. BRAKE TEST CALCULATIONS

Definitions

KE $\triangleq$ kinetic energy

IE $\triangleq$ inertia equivalent (weight at periphery of flywheel)

V $\triangleq$ velocity (FPS)

RPM $\triangleq$ revolutions per minute

RPS $\triangleq$ revolutions per second

F $\triangleq$ force at periphery of flywheel

RR $\triangleq$ rolling radius (loaded tire measurement from center of axle to ground)

Desired Conditions

KE = 8.7×10^6 ft-lbs

Initial brake RPM = 882 or 14.7 RPS

RR = 24.2 inches

Effective circumference = $\pi \times D = 3.14 \times 2 \times \frac{24.2}{12}$

Effective circumference = 12.7 feet

Flywheel surface speed = circumference x RPS

Flywheel surface speed = 12.7 ft x 14.7 RPS

Flywheel surface speed = 187 FPS = 509 RPM

Calculations

$$KE = \frac{IE}{2g} \times V^2$$

$$IE = \frac{64.4 \times KE}{V^2} = \frac{64.4 \times 8.7 \times 10^6}{187^2}$$

$$IE = 16{,}000 \text{ lbs}$$

The 84-inch flywheel, with 1 plates on the east side and 9 plates on the west side, has an IE of 15,901 pounds which is slightly less than the desired IE to compensate for this, the RR was changed. The new RR was determined by the following method:

$$V = \sqrt{\frac{64.4\ KE}{IE}}$$

$$V = \sqrt{\frac{64.4 \times 8.7 \times 10^6}{15,901}} = 187.7\ \text{FPS}$$

$$V = 512\ \text{RPM of flywheel}$$

The RR must be corrected for the proper RPM.

$$\text{Tire circumference} = \frac{\text{flywheel surface speed}}{\text{brake RPS}}$$

$$\pi \times 2 \times RR = \frac{187.7\ \text{FPS} \times 12\ \text{inch/ft}}{14.7\ \text{RPS}}$$

$$RR = 24.4\ \text{inches}$$

The inflation pressure of the tire was adjusted to a rolling radius of 24.4 inches at a tire load of 40,000 pounds.

2. COEFFICIENT OF FRICTION CALCULATION

Basic Equation

$F = \mu N$

Definitions

$F \triangleq$ pulling force (pounds)

$\mu \triangleq$ coefficient of friction (dimensicnless)

$N \triangleq$ normal force on the brake (pounds)

The pulling force (F) is determined by dividing the brake torque (T) by the distance from the brake center to the wear pads (R). The force (F) is then divided by eight because there are eight braking surfaces.

The normal force (N) is found by multiplying the brake pressure (P) by the total piston area (A).

Given Data for Run 50

Radius = 10.1 inches

Twelve pistons with a diameter = 1.375 inches

Brake pressure = 1.25×10^3 PSI

Brake torque = 3.0×10^5 inch-lbs

$$A = 12 \times \frac{\pi}{4} \times D^2 = 12 \times \frac{\pi}{4} \times (1.375)^2$$

$$A = 17.8 \text{ in}^2$$

$$F = \frac{3.0 \times 10^5 \text{ in-lbs}}{10.1 \text{ in} \times 8} = 3.71 \times 10^3 \text{ lbs}$$

$$N = 1.25 \times 10^3 \text{ PSI} \times 17.8 = 2.22 \quad 10^4 \text{ lbs}$$

$$\mu = \frac{F}{N} = \frac{3.71 \times 10^3 \text{ lbs}}{2.22 \times 10^4 \text{ lbs}}$$

$$\mu = 0.167$$

APPENDIX II

SUMMARY OF BRAKE TEST DATA

SUMMARY OF BRAKE TEST DATA

Event or cycle number	Time between stops/25 cycles (minutes)	Stop time/ 25 cycles (seconds)	Brake pressure/ 25 cycles (PSI)			Brake torque/ 25 cycles (lbs x 10^4)			Stop distance/ 25 cycles (feet)
			Max	Min	Avg	Max	Min	Avg	
Data for Bendix Cerametallic Brake 1									
1-25	35	11.0	2500	100	1495	48	4	24.5	1562
26-50	40	10.9	2828	175	2460	46	11	29.0	1450
51-75	60	10.8	2725	125	1950	43	8	30.0	1540
76-95	40	11.1	1500	110	1131	31	8	26.9	1184
Data for Bendix Cerametallic Brake 2									
1-25	44	11.0	1825	100	1193	30	8	27.0	1166
26-50	51	10.7	1400	100	1148	33	9	27.3	1100
51-75	49	11.2	1400	75	1188	32	9	27.5	1047
76-100	46	12.6	1450	0	1145	33	0	27.5	1188
101-125	49	11.0	1450	85	1204	32	9	28.8	1074
126-150	46	10.8	1400	90	1178	33	8	28.6	1113
151-166	46	11.5	1400	100	1135	33	8	28.8	1113
Data for Sintered Metal Brake									
1-25	53	11.3	1625	125	1134	31	9	27.0	1258
26-50	54	11.4	1800	100	1429	30	8	27.0	1184
51-75	51	11.5	1750	100	1434	31	6	26.8	1179
76-100	48	11.7	1690	95	1389	32	6	26.9	1146
101-125	46	11.4	1700	75	1435	32	9	28.0	1137
126-150	46	11.4	1725	75	1434	32	8	28.0	1133

SUMMARY OF BRAKE TEST DATA (Continued)

Event or cycle number	Time between stops/25 cycles (minutes)	Stop time/ 25 cycles (seconds)	Brake pressure/ 25 cycles (PSI)			Brake torque/ 25 cycles (lbs x 10^4)			Stop distance/ 25 cycles (feet)
			Max	Min	Avg	Max	Min	Avg	
Data for Sintered Metal Brake (Continued)									
151-175	45	11.4	1675	75	1381	33	8	28.3	1100
176-200	47	11.6	1575	60	1321	32	8	28.6	1089
201-225	46	11.4	1550	75	1303	32	9	26.3	1093
226-250	46	11.2	1500	75	1241	32	9	27.9	1100
251-275	47	11.2	1500	75	1235	32	7	27.9	1066
276-300	47	11.3	1500	75	1249	32	9	28.7	1091
301-325	48	11.4	1500	75	1260	32	7	28.4	1098
326-350	46	11.3	1550	75	1295	33	8	27.8	1115
351-375	47	11.5	1625	75	1347	33	8	31.0	1146
376-400	46	11.5	1700	75	1399	33	8	29.3	1153
401-429	54	11.2	1750	75	1399	32	8	27.0	1184

APPENDIX III

DATA FOR BENDIX CERAMETALLIC BRAKE 1

DATA FOR CERAMETALLIC BRAKE 1

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Remarks
			Max	Min	Max	Min		
1	-	10.5	500	0		22	-	
2	-	12.0	750	100		21	79	
3	-	-				-	-	No data
4	-	11				-	53	
5	-	11	1150	175	30	10	56	
6	55	11	1100	160	30	12	57	
7	30	11	1000	250	30	12	70	
8	50	10.0	1775	250	30	14	57	
9	40	0.3	1900	0	12	0	53	Abort - system trouble
10	95	14.0	1575	460	34	17	111	
11	40	7.0	2450	0	22	0	60	Abort - system trouble
12	40	11.6	2050	0	48	39	115	
13	40	0.5	2500	0	13	0	32	Abort - system trouble
14	15	16.0	875	175	29	4	100	
15	40	14.2	1950	195	28	3	71	
16	40	1.0	2450	0	16	0	42	Abort - system trouble
17	65	11.0	1250	255	30	16	78	
18	40	2.5	2450	0	20	0	56	Abort - system trouble
19	65	0.5	2450	0	6	0	23	Abort - system trouble
20	10	2.2	2450	0	8	0	29	Abort - system trouble

DATA FOR CERAMETALLIC BRAKE 1 (Continued)

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Remarks
			Max	Min	Max	Min		
21	50	11.1	2400	175	30	10	58	Pin measured at 0.190 inch at 250 PSI.
22	180	11.2	1150	150	30	10	60	
23	35	9.1	1025	400	33	16	79	
24	25	11.0	1425	175	30	9	59	
25	30	11.1	1420	175	31	10	59	
26	40	11.2	1120	150	31	10	67	
27	30	11.2	1025	170	31	10	90	
28	40	10.4	2350	180	31	11	57	
29	40	10.9	2650	200	32	10	60	
30	40	10.9	2625	225	32	11	59	
31	40	10.8	2650	225	33	11	68	Filter had to be cleaned
32	40	10.5	2700	200	31	11	56	
33	40	12.4	1150	200	31	12	86	
34	40	14.0	900	550	37	25	131	
35	40	13.0	1550	0	46	34	102	Filter had to be cleaned
36	40	10.4	2700	200	31	11	58	
37	40	10.7	2750	200	31	11	59	
38	40	10.6	2750	200	32	11	59	
39	20	10.6	2325	200	32	11	62	
40	40	10.9	2500	175	31	11	62	
41	40	11.0	2700	190	31	11	62	Filter had to be cleaned

DATA FOR CERAMETALLIC BRAKE 1 (Continued)

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Remarks
			Max	Min	Max	Min		
42	40	11.0	2650	200	32	10	59	
43	40	12.2	2575	175	33	11	71	Filter had to be cleaned
44	40	10.9	2775	175	31	11	57	
45	40	11.0	2650	175	32	10	63	
46	40	10.9	2650	200	32	11	62	Filter had to be cleaned
47	40	10.8	2550	175	31	10	58	
48	40	10.9	2650	195	32	10	63	
49	40	10.9	2500	200	32	11	76	Filter had to be cleaned
50	40	10.6	2825	195	31	11	59	
51	40	10.9	2700	195	32	11	59	
52	40	11.2	2575	195	32	11	67	Pin measured at 0.287 inch. At 250 PSI, booster recharged and brake bled.
53	100	10.8	1250	200	30	11	58	
54	280	10.5	1260	170	30	10	55	
55	55	10.6	1200	160	30	11	59	
56	65	10.0	1260	125	30	8	58	
57	110	9.5	1250	300	30	16	56	
58	80	10.0	1150	275	29	14	70	
59	40	9.8	1175	300	30	14	61	
60	80	10.2	1250	300	30	14	62	

DATA FOR CERAMETALLIC BRAKE 1 (Continued)

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Remarks
			Max	Min	Max	Min		
61	290	9.8	1300	300	30	16	58	
62	120	10.9	950	290	29	14	96	
63	50	6.9	840	795	41	38	177	
64	55	9.1			43	38	153	
65	125	13.5			62	59	151	
66	115	10.2	1050	290	29	13	84	Brake disassembled and inspected. Pin measured at 0.341 inch at 250 PSI.

DATA FOR CERAMETALLIC BRAKE 1 (Continued)

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Temperatures (°F)											
								Rotor 1		Rotor 2		Rotor 3		Rotor 4		Piston housing		Pressure plate	
			Max	Min	Max	Min		Start	Max	Start	Max	Start	Max	Start	Max	Start	Max	Start	Max
67*	–	10.7	2725	140	31	10	49	80	195	80	195	Faulty thermocouple connection		Faulty thermocouple connection		80	160	80	160
68	20	10.8	2700	140	31	10	53	95	215	95	215					95	215	95	215
69	15	10.9	2400	125	31	9	52	95	240	95	240					95	240	95	240
70	15	11.0	1950	125	30	9	53	195	275	195	275					195	275	195	275
71	10	11.1	2450	150	30	9	53	180	280	180	280					180	280	180	280
72	15	11.0	2640	150	30	9	57	190	270	190	270					190	270	190	270
73	35	11.0	1250	125	30	9	54	145	235	145	235					145	235	145	235
74	20	10.8	1250	150	31	10	55	150	255	150	255					150	255	150	255
75	10	11.0	1150	150	31	9	56	195	285	195	285					195	285	195	285
76	10	11.0	1325	140	31	10	53	185	285	185	285					185	285	185	285
77	20	11.0	1325	145	31	9	57	175	255	175	255					175	255	175	255
78	15	11.0	1300	150	30	9	55	200	275	200	275					200	275	200	275
79	10	11.1	1250	140	30	9	55	190	250	190	250					190	250	190	250
80	5	11.0	1275	150	30	9	55	190	275	190	275					190	275	190	275
81	20	11.0	1400	150	31	9	56	185	265	185	265					185	265	185	265
82	15	11.1	1250	150	31	9	55	170	250	170	250					170	250	170	250
83	–	11.1	1500	150	30	10	56												
84	65	11.0	1390	125	30	9	52												
85	55	11.0	1425	125	30	9	54												
86	60	11.0	1400	130	30	9	53												
87	55	11.1	1360	135	30	9	56												
88	55	11.1	1400	125	30	8	55												
89	55	11.1	1350	125	30	8	53												
90	60	11.0	1325	125	30	9	53												
91**	60	11.0	1325	110	30	9	54												
92	65	11.0	1250	125	30	9	50												
93***	55	11.3	550	con-stant	23.3		56												
94	50	11.3	1300	120	30	8	50												
95†	35	11.0	1300	115	30	8	48												

*The temperatures from 67 through 82 are incorrect temperatures because the thermocouple and brake are making poor contact

**Pin measured at 0.460 inch at 250 PSI

***Programmed for constant torque

† Test discontinued due to pulsating brake pressure

APPENDIX IV

DATA FOR BENDIX CERAMETALLIC BRAKE 2

DATA FOR CERAMETALLIC BRAKE 2

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Remarks
			Max	Min	Max	Min		
1	-	11.0	1825	200	30	10	52	Pin measured at 0.109 inch at 250 PSI
2	40	11.0	1150	200	30	10	51	
3	40	11.1	1175	140	30	8	54	
4	40	11.1	1275	125	30	8	54	
5	40	11.1	1150	125	30	8	55	
6	40	11.1	1275	200	30	8	50	
7	40	11.1	1300	100	30	8	54	
8	40	11.0	1350	100	30	8	52	
9	40	11.1	1300	100	30	8	53	
10	40	11.0	1375	100	30	8	50	
11	40	11.2	1400	100	30	8	51	
12	40	11.0	1350	100	30	8	53	
13	40	11.2	1410	110	30	8	51	
14	40	10.9	1375	100	30	8	50	
15	40	11.1	1375	100	30	8	52	
16	40	11.1	1350	100	30	8	52	
17	40	11.4	1390	100	30	8	52	Pin measured at 0.230 inch at 250 PSI
18	40	11.0	1350	100	30	8	57	
19	40	11.2	1400	100	30	8	53	
20	40	11.0	1550	100	30	8	55	Pin measured at 0.236 inch at 250 PSI

DATA FOR CERAMETALLIC BRAKE 2 (Continued)

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Remarks
			Max	Min	Max	Min		
21	-	11.1	1425	100	30	8	54	
22	30	10.8	1450	125	30	9	53	
23	55	11.0	1450	100	30	9	55	
24	60	10.8	1475	125	30	10	54	
25	60	10.8	1350	100	30	9	56	
26	50	10.7	1400	170	31	10	52	
27	80	10.2	1300	150	33	11	55	Pin measured at 0.267 inch at 250 PSI
28	50	11.4	1250	125	30	9	62	
29	40	11.4	1325	125	30	9	57	
30	55	11.3	1350	125	30	9	57	
31	-	10.9	1400	125	30	9	53	
32	45	10.9	1400	125	32	10	50	Pin measured at 0.270 inch at 250 PSI. One link on #3 rotor failed. Brake was torn down and inspected. Motor #1 had indications of warped segments. Rotors 1 and 3 replaced with rotors 1 and 2 from Bendix brake No. 1 which had 95 arrestments.
33	-	11.2	1275	125	32	9	48	
34	45	11.2	1300	120	32	10	49	Pin measured at 0.294 inch at 250 PSI

DATA FOR CERAMETALLIC BRAKE 2 (Continued)

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Remarks
			Max	Min	Max	Min		
35	45	11.0	1300	100	32	10	48	
36	45	10.8	1200	100	33	10	48	
37	45	11.1	1175	100	33	10	48	
38	45	11.1	1300	100	32	10	49	
39	45	11.0	1350	100	32	10	48	
40	45	11.1	1375	100	32	10	48	
41	45	10.9	1350	100	32	10	47	
42	45	10.9	1350	100	32	10	48	
43	100	11.0	1350	100	31	10	47	
44	45	11.2	1350	100	31	10	49	
45	80	11.1	1325	100	31	10	47	
46	45	11.1			31	10	48	
47	45	11.3	1300	100	31	10	48	
48	45	11.2	1300	100	31	10	49	
49	45	11.1	1325	100	31	11	48	
50	45	11.3			31	9	49	
51	45	11.3	1325	90	31	9	47	
52	105	11.3	1325	100	31	11	50	
53	45	11.3	1350	110	31	11	50	
54	45	11.3	1375	110	32	11	49	Pin measured at 0.360 inch at 250 PSI
55	45	11.3	1375	100	31	11	49	
56	45	11.2	1350	90	31	10	45	

DATA FOR CERAMETALLIC BRAKE 2 (Continued)

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Remarks
			Max	Min	Max	Min		
57	45	11.0	1400	90	32	10	46	
58	75	11.0	1400	90	32	10	46	
59	45	11.0	1325	100	32	10	46	
60	45	11.3	1350	90	31	9	47	
61	45	11.2	1375	75	31	9	48	
62	45	11.3	1375	90	31	9	48	
63	45	11.2	1375	75			48	
64	45	11.0	1400	75	32	9	48	
65	45	11.0	1375	75	32	9	48	
66	45	10.9	1400	75	32	9	47	
67	45	11.0	1375	100	32	9	47	
68	45	11.0	1375	100	32	9	47	
69	45	11.0	1375	100	32	10	48	
70	45	11.0	1375	100	32	10	48	
71	45	10.9	1375	75	32	9	48	
72	45	11.0	1350	75	32	9	48	
73	45	11.0	1375	75	32	9	47	
74	45	11.0	1350	90	32	9	48	
75	45	11.0	1325	80	32	9	48	
76	45	11.1	1350	90	32	9	47	
77	45	39.2	775	0	13	0	111	Instrument air pressure was low
78	45	39.2	775	20			108	

DATA FOR CERAMETALLIC BRAKE 2 (Continued)

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Remarks
			Max	Min	Max	Min		
79	45	11.0	775	200	13	8	77	Brake pressure and torque were low. Filter was cleaned.
80	45	11.0	1310	90	31	8	50	
81	45	10.9	1360	90	32	9	48	
82	45	11.1	1380	90	31	9	48	
83	45	11.0	1400	100	32	9	48	
84	45	11.0	1350	75	32	9	50	
85	45	11.1	1350	75	32	9	48	
86	45	11.1	1375	90	32	9	49	
87	45	11.1	1400	75	32	10	48	Pin measured at 0.453 inch at 250 PSI.
88	45	11.0	1400	90	32	10	48	
89	60	11.0	1450	90	32	10	47	
90	45	11.0	1400	90	32	9	47	
91	45	11.0	1400	100	32	9	47	
92	45	10.8	1400	100	32	10	47	
93	45	11.1	1400	100	32	9	47	
94	45	11.2	1450	100	33	10	48	
95	45	11.0	1400	100	33	10	48	
96	45	10.9	1400	100	32	10	48	
97	45	11.0	1400	100	32	10	48	
98	45	11.0	1375	90	32	10	48	
99	45	10.8	1400	100	32	10	46	

DATA FOR CERAMETALLIC BRAKE 2 (Continued)

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Remarks
			Max	Min	Max	Min		
100	45	10.8	1425	100	33	9	50	
101	45	10.8	1425	100	32	10	48	
102	45	11.0	1350	100	32	9	49	
103	45	11.0	1375	100	32	10	48	
104	45	11.0	1425	100	32	10	48	
105	90	11.1	1350	90	32	9	48	Brake pump was not on and in no torque or brake pressure. Attempt was made twice.
106	45	10.9	1350	90	32	9	48	
107	45	11.0	1360	90	31	10	49	
108	45	10.9	1380	90	32	9	48	
109	45	11.0	1360	90	32	9	49	
110	45	10.9	1410	90	32	9	48	
111	45	11.0	1350	85	32	9	51	
112	45	11.0	1390	90	32	9	49	
113	45	11.1	1360	90	32	9	49	
114	-	11.0	1375	100	32	10	47	Pin measured at 0.531 inch at 250 PSI.
115	45	11.0	1375	100	32	10	49	
116	45	11.1	1425	100	32	10	48	
117	45	11.0	1350	100	32	10	48	
118	45	11.1	1325	100	32	10	48	
119	75	10.8	1400	100	32	10	49	

DATA FOR CERAMETALLIC BRAKE 2 (Continued)

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Remarks
			Max	Min	Max	Min		
120	45	11.0	1400	100	32	10	50	
121	45	11.0	1450	100	32	10	50	
122	45	11.0	1400	100	32	10	49	
123	45	11.1	1400	90	32	9	50	
124	65	10.9	1425	100	32	10	50	
125	45	11.0	1325	100	32	9	49	
126	45	11.0	1390	100	32	9	51	
127	45	11.1	1400	100	32	9	50	
128	45	11.2	1400	100	32	9	49	
129	45	11.2	1375	100	32	9	51	
130	45	11.2	1400	100	32	9	50	
131	45	11.3	1400	100	32	9	52	
132	45	11.1	1400	100	32	9	50	
133	45	11.1	1340	100	31	9	51	
134	45	11.1	1355	100	32	9	49	Pin measured at 0.576 inch at 250 PSI.
135	45	11.4	1300	100	31	9	50	
136	45	11.2	1325	100	32	9	49	
137	45	11.1	1325	90	31	9	49	
138	45	11.0	1375	110	32	10	50	
139	45	11.3	1375	100	32	10	50	
140	45	11.2	1340	100	32	10	50	
141	45	11.3	1375	110	32	10	50	
142	45	11.2	1325	100	32	10	51	Pin measured at 0.608 inch at 250 PSI.

DATA FOR CERAMETALLIC BRAKE 2 (Continued)

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Remarks
			Max	Min	Max	Min		
143	45	11.3	1325	100	31	10	52	
144	45	11.1	1325	110	33	11	51	
145	40	11.1	1250	100	32	10	49	
146	45	12.0	1350	125	32	12	58	
147	45	11.6	1375	125	32	12	57	Pin measured at 0.625 inch at 250 PSI.
148	45	11.5	1325	100	31	8	49	
149	45	11.4	1325	100	31	8	49	
150	75	11.2	1375	100	31	9	48	
151	45	11.4	1350	100	31	9	49	Pin measured at 0.635 inch at 250 PSI.
152	45	11.5	1400	100	32	9	50	
153	45	11.5	1325	100	31	8	49	
154	45	11.5	1350	100	32	9	50	Pin measured at 0.649 inch at 250 PSI.
155	55	11.2	1325	100	32	9	49	
156	45	11.4	1250	100	31	9	50	
157	45	11.4	1200	125	31	8	51	
158	45	11.4	1200	125	32	8	51	
159	45	11.2	1240	140	33	8	51	
160	45	11.0	1250	125	33	9	52	
161	45	12.0	1250	140			53	
162	55	11.2	1400	125	33	9	51	Pin measured at 0.688 inch at 250 PSI.
163	40	12.0	1375	125	32	9	51	

DATA FOR CERAMETALLIC BRAKE 2 (Continued)

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Remarks
			Max	Min	Max	Min		
164	50	12.1	1275	125	32	9	51	
165	45	11.1	1350	105	32	9	51	Pin measured at 0.705 inch at 250 PSI.
166	45	11.4	1325	125	32	9	50	Pin measured at 0.713 inch. Test terminated because brake had worn out.

APPENDIX V

DATA FOR BLISS SINTERED METAL BRAKE

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10−4)		Flywheel revolutions	Temperatures												Remarks
								Rotor 1		Rotor 2		Rotor 3		Rotor 4		Piston housing		Pressure plate		
			Max	Min	Max	Min		Start	Max	Start	Max	Start	Max	Start	Max	Start	Max	Start	Max	
1	—	—	1625	400	31	14	57	95	380	95	330	Faulty Thermocouple Connection		95	360	95	105	95	250	Pin measured at 0.216 inch at 250 PSI
2	55	10.7	1100	350	31	14	74	180	460	180	460			115	490	85	110	95	250	Pin measured at 0.179 inch at 250 PSI
3	—	10.3	1100	450	30	14	60	70	415	70	—			70	470	70	90	70	205	Pin measured at 0.158 inch at 250 PSI
4	55	11.2	1000	225	30	10	55	195	500	195	510			195	540	85	95	90	235	Pin measured at 0.150 inch at 250 PSI
5	65	11.4	1000	175	30	9	56	185	565	130	565			175	575	80	90	100	210	Pin measured at 0.164 inch at 250 PSI
6	35	11.3	1000	180	30	10	58	180	545	180	545			180	545	75	90	100	210	Pin measured at 0.168 inch at 250 PSI
7	40	11.7	1050	150	30	10	61	180	550	180	550			180	550	75	90	100	210	Pin measured at 0.150 inch at 250 PSI
8	35	11.5	1175	150	30	9	53	115	500	115	500			115	500	75	90	85	195	Pin measured at 0.149 inch at 250 PSI
9	45	11.3	1075	200	30	12	74	195	565	195	565			195	565	85	95	100	210	Pin measured at 0.152 inch at 250 PSI
10	40	11.3	1260	140	30	10	51	195	595	195	595			195	595	80	90	105	205	
11	50	11.6	1150	150	30	10	63	160	580	160	—			160	580	80	90	90	205	Pin measured at 0.156 inch at 250 PSI
12	45	11.4	1300	140	30	10	54	180	595	180	595			Faulty Thermocouple Connection		80	95	100	210	Rotor 4 thermocouple failed
13	55	11.7	1250	140	30	10	59	180	610	180	610					80	90	90	190	
14	85	11.2	1400	150	30	9	56	125	540	125	540					75	180	80	175	
15	45	11.2	1400	125	30	9	53	190	590	190	590					80	90	90	190	
16	50	11.2	1400	150	30	9	55	190	610	190	610					90	90	100	195	
17	50	—	1345	140	30	10	52	190	620	190	620					80	90	90	190	
18	55	11.4	1475	125	30	9	52	200	580	200	580					75	95	80	180	
19	45	11.2	1500	150	30	9	52	190	520	190	520					75	90	80	200	
20	70	11.4	1550	125	30	9	52	150	565	150	565					75	80	80	175	
21	50	11.6	1540	125	30	9	52	170	540	170	540					75	80	80	175	
22	50	11.6	1475	125	30	9	55	195	590	195	590					75	80	80	175	
23	50	11.6	1500	125	30	9	54	185	610	185	610					70	75	75	170	
24	50	11.6	1450	125	30	10	61	190	595	190	505					70	80	70	160	
25	45	11.6	1470	125	29	9	60	200	550	200	660					70	80	75	170	
26	60	11.7	1390	130	30	10	63	190	580	190	580					70	75	75	165	
27	50	11.5	1595	125	30	9	54	260	580	200	580					70	75	70	165	
28	45	11.5	1500	125	30	10	58	200	590	200	610					70	75	75	175	
29	45	—	1500	125	30	10	58	200	635	200	645					70	75	70	165	Pin measured at 0.188 inch at 250 PSI
30	60	11.3	1450	150	30	11	64	155	560	155	560					65	75	75	160	
31	60	11.2	1575	140	30	10	53	165	560	165	560					65	80	70	160	
32	60	11.2	1660	140	30	10	53	160	535	160	535					75	80	85	160	
33	45	11.2	1650	140	30	10	52	175	595	175	585					70	85	70	180	
34	90	11.3	1575	140	30	10	55	100	530	100	—					70	80	70	160	
35	[illegible]	11.3	1675	100	30	9	52	185	600	185	600					70	80	70	165	
36	45	12.0	1650	100	30	8	52	195	555	195	-					70	85	70	175	
37	60	11.8	1600	100	30	9	54	170	565							70	80	70	165	Removed filter; Rotor 2 thermocouple became inoperative.
38	50	11.3	1670	100	30	8	50	200	610	Faulty Thermocouple Connection						70	80	70	165	
39	50	11.5	1775	100	30	8	52	190	560							70	80	70	165	
40	55	11.6	1700	100	30	8	51	200	580							70	80	70	160	
41	45	11.4	1600	200	30	8	54	190	600							70	80	70	165	
42	40	11.4	1700	200	30	8	53	200	625							70	80	70	163	
43	60	11.4	1700	200	30	8	54	170	580							70	80	70	170	Rotor 2 thermocouple failed
44	55	11.5	1725	200	30	8	54	200	600							70	80	70	165	
45	50	11.4	1750	200	30	8	52	200	610							75	80	75	165	
46	55	11.4	1750	200	30	8	51	190	555							70	80	70	165	
47	60	11.4	1725	200	30	8	52	190	555							75	80	75	170	
48	60	11.4	1740	110	30	8	52	140	545							75	80	75	165	
49	45	11.5	1800	100	30	8	50	190	580							75	85	75	170	
50	50	11.4	1625	110	30	8	53	190	585							75	80	75	170	
51	50	11.4	1690	110	30	8	52	185	585							75	85	75	175	
52	50	11.4	1700	110	30	8	52	200	580							75	85	75	165	
53	55	11.3	1750	110	30	8	52	165	565							75	80	75	165	
54	50	11.3	1725	100	30	8	52	200	585							75	85	75	165	

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Temperatures												Remarks
								Rotor 1		Rotor 2		Rotor 3		Rotor 4		Piston housing		Pressure plate		
			Max	Min	Max	Min		Start	Max	Start	Max	Start	Max	Start	Max	Start	Max	Start	Max	
55	50	11.5	1700	110	30	S	52	170	575							70	80	70	160	
56	45	—	—	—	—	-	53	190	595							70	80	70	165	Pin measured at 0.220 inch at 250 PSI
57	65	11.4	1650	110	30	9	54	195	565							75	85	80	175	
58	60	11.4	1650	110	30	9	51	165	555							70	80	80	195	
59	45	11.5	1675	110	30	9	49	190	575							70	80	80	205	
60	60	11.4	1750	110	30	9	49	190	565							65	80	75	195	
61	30	11.3	1750	110	30	8	49	110	540							60	75	65	180	
62	50	11.4	1750	110	30	8	49	180	565							65	75	75	200	Pin measured at 0.230 inch at 250 PSI. Brake torn down and inspected. Thermocouples removed.
63	—	10.5	1650	175	31	12	49			Faulty Thermocouple Connection		Faulty Thermocouple Connection		Faulty Thermocouple Connection						
64	35	11.5	1620	100	30	8	57													
65	60	11.4	1650	100	30	8	59													
66	50	11.5	1675	100	30	8	61													
67	45	11.9	1660	100	30	8	59													
68	45	11.7	1660	100	30	8	61													
69	45	11.7	1625	100	30	8	54													
70	45	11.6	950	550	22.2	-	57													Constant torque stop
71	45	11.5	1650	100	30	8	52													
72	45	11.7	1675	100	30	8	54													
73	45	11.7	1650	100	30	8	53													
74	45	11.7	1650	100	30	8	54													
75	45	11.7	1650	100	30	8	55													
76	45	11.7	1650	100	30	8	54													
77	45	11.3	1650	100	30	8	54													
78	45	11.9	1650	100	30	8	53													
79	45	11.8	1650	100	30	8	53													
80	45	11.4	1690	100	30	8	53													
81	45	11.8	1690	95	30	8	52													
82	45	11.8	1610	100	29	8	52													Pin measured at 0.252 inch at 250 PSI
83	45	11.7	1625	95	30	8	52													
84	45	11.8	1610	95	29	8	55													
85	45	11.7	1640	95	30	8	52													
86	45	11.9	[illegible]25	95	29	8	53													
87	45	11.7	1600	100	30	8	52													
88	45	11.7	1625	100	29	8	51													
89	45	11.8	1660	95	30	8	51													
90	45	11.7	1625	100	29	8	54													Pin measured at 0.252 inch at 250 PSI
91	40	11.7	1660	100	30	8	52													
92	45	11.7	1625	100	30	8	53													
93	65	11.6	1650	100	30	8	51													
94	40	11.6	1650	100	30	8	52													
95	105	11.6	1650	100	30	8	52													
96	45	11.6	1650	100	30	8	51													
97	45	11.7	1650	100	30	8	51													
98	45	11.7	1650	90	30	8	50													Pin measured at 0.259 inch at 250 PSI
99	45	12.4	1575	100	30	6	52													
100	45	11.1	1550	100	32	9	48													Wheel skidded - cause was unknown
101	—	11.4	1650	100	31	9	50													
102	50	11.4	1675	100	31	9	50													
103	45	11.0	1700	100	32	9	50													
104	45	11.5	1650	100	31	9	51													
105	45	11.5	1650	75	32	9	53													
106	60	11.1	1650	75	32	9	52													Pin measured at 0.280 inch at 250 PSI
107	45	11.4	1675	75	31	9	51													
108	45	—	1600	75	31	9	52													

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10−4)		Flywheel revolutions	Temperatures												Remarks
								Rotor 1		Rotor 2		Rotor 3		Rotor 4		Piston housing		Pressure plate		
			Max	Min	Max	Min		Start	Max	Start	Max	Start	Max	Start	Max	Start	Max	Start	Max	
109	45	11.6	1625	75	31	9	51			Faulty Thermocouple Connection		Faulty Thermocouple Connection		Faulty Thermocouple Connection						
110	45	11.5	1650	75	31	9	50													
111	45	11.6	1625	75	31	9	52													
112	45	11.5	1650	75	31	9	55													
113	45	11.5	1650	75	31	9	53													
114	45	11.5	1700	75	31	9	53													
115	45	11.6	1650	75	31	9	52													
116	45	11.4	1625	80	31	9	54													
117	45	11.3	1625	75	31	9	52													
118	45	11.4	1675	75	31	9	52													
119	45	11.4	1650	75	31	9	52													
120	45	11.4	1625	75	31	9	51													
121	45	11.6	1640	75	31	9	51													Pin measured at 0.290 inch at 250 PSI
122	45	11.4	1660	75	31	9	52													
123	45	11.4	1675	75	31	9	52													
124	45	11.5	1625	75	31	9	51													
125	45	11.2	1640	75	31	9	51													
126	45	11.4	1660	75	31	9	52													
127	45	11.4	1675	75	31	9	51													
128	45	11.3	1675	75	31	8	53													
129	45	11.5	1655	75	31	8	52													
130	45	11.4	1625	75	31	8	52													
131	45	11.6	1625	75	31	9	51													Pin measured at 0.300 inch at 250 PSI
132	45	11.4	1650	75	31	9	53													
133	45	11.4	1625	75	31	9	51													
134	45	11.5	1650	75	31	9	59													
135	45	11.4	1625	75	31	9	53													
136	45	11.5	1700	75	31	9	53													
137	75	11.4	1725	75	31	9	53													
138	45	11.4	1625	75	31	9	51													
139	45	11.4	1650	75	31	9	49													
140	45	11.4	1650	75	31	9	50													
141	45	11.5	1675	75	31	9	49													
142	45	11.4	1625	75	31	9	50													
143	45	11.4	1650	75	31	9	50													
144	45	11.4	1625	75	31	9	50													
145	45	11.3	1675	75	32	9	50													
146	45	11.4	1600	75	31	9	50													
147	45	11.5	1625	75	32	9	51													
148	45	11.3	1675	75	32	9	51													
149	45	11.5	1625	75	31	9	52													
150	45	11.4	1600	75	31	9	51													
151	45	11.4	1650	75	31	9	49													
152	45	11.4	1675	75	32	9	49													Pin measured at 0.323 inch at 250 PSI
153	45	11.5	1600	75	31	9	51													
154	45	11.3	1625	90	31	9	50													
155	45	11.3	1650	90	31	10	49													
156	45	11.5	1625	90	31	9	50													
157	45	11.5	1600	95	31	9	50													
158	45	11.4	1600	90	31	10	49													
159	45	11.3	1525	90	31	10	50													
160	45	11.3	1560	90	31	9	50													
161	45	11.4	1600	90	31	9	49													
162	45	11.4	1575	90	31	10	51													
163	45	11.3	1550	90	31	9	50													

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10-4)		Flywheel revolutions	Temperatures												Remarks
								Rotor 1		Rotor 2		Rotor 3		Rotor 4		Piston housing		Pressure plate		
			Max	Min	Max	Min		Start	Max	Start	Max	Start	Max	Start	Max	Start	Max	Start	Max	
164	45	11.4	1625	90	31	10	53													
165	45	11.4	1525	90	31	10	50													
166	45	11.3	1640	75	32	9	50													
167	45	11.3	1575	75	32	9	49													
168	45	11.3	1600	75	32	9	49													
169	45	11.3	1600	75	32	9	50													
170	45	11.4	1550	90	32	9	51													
171	45	11.3	1575	75	32	9	48													
172	45	11.1	1625	75	33	9	48													Pin measured at 0.363 inch at 250 PSI
173	45	11.6	1600	75	32	8	49													
174	45	11.5	1525	75	32	8	50													
175	45	11.5	1575	75	32	8	50													
176	45	11.5	1525	75	32	8	49													
177	45	11.6	1550	75	32	8	50													
178	45	11.5	1525	75	32	8	48													
179	90	11.4	1575	75	32	8	50													Instrument air pressure was too low
180	45	11.5	1550	75	32	8	50													
181	45	11.6	1525	75	32	8	49													
182	45	11.6	1500	75	32	8	50													
183	45	11.4	1550	75	32	8	50													
184	45	11.8	1500	75	32	8	49													
185	45	11.5	1500	60	32	8	50													
186	45	11.6	1500	75	32	8	49													
187	45	11.6	1525	75	32	8	50													
188	45	11.6	1500	75	31	8	50													
189	45	11.7	1540	70	31	9	48													
190	45	11.7	1550	75	32	8	49													
191	45	11.6	1550	75	32	8	50													
192	45	11.6	1500	75	31	8	49													
193	45	11.6	1500	75	32	8	50													
194	45	11.7	1550	60	32	8	49													
195	45	11.7			32	8	51													
196	45	11.7	1550	75	32	8	49													Pin measured at 0.362 inch at 250 PSI
197	45	11.6	1500	75	32	8	49													
198	45	11.6	1450	75	31	9	50													
199	45	11.0	1475	120	32	9	49													
200	60	11.2	1450	100	32	9	50													Brake disassembled and inspected
201	—	11.3	1400	100	31	10	49													Pin measured at 0.370 inch at 250 PSI
202	45	11.3	1475	100	32	10	51													
203	45	11.3	1460	100	31	10	51													
204	50	11.4	1550	75	31	10	51													
205	60	11.3	1500	90	32	10	49													
206	45	11.4	1550	80	22	10	50													
207	45	11.3	1500	75	31	10	50													
208	45	11.3	1475	80	32	10	49													
209	45	11.2	1500	80	32	9	51													
210	45	11.2	1500	75	32	10	49													
211	45	11.3	1525	80	32	10	50													
212	45	11.3	1500	75	31	10	49													
213	45	11.2	1500	75	31	10	50													
214	45	11.4	1500	75	32	10	50													
215	45	11.4	1525	75	32	10	51													
216	45	11.3	1500	75	31	9	50													
217	45	11.3	1540	180	32	9	51													
218	45	11.3	1460	70	31	10	50													

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Temperatures												Remarks
								Rotor 1		Rotor 2		Rotor 3		Rotor 4		Piston housing		Pressure plate		
			Max	Min	Max	Min		Start	Max	Start	Max	Start	Max	Start	Max	Start	Max	Start	Max	
219	45	11.5	1500	75	31	9	48													
220	45	11.5	1525	75	31	9	49													
221	45	11.5	1500	75	31	9	49													
222	45	11.4	1500	75	31	9	49													
223	45	11.5	1475	75	31	9	50													
224	45	11.6	1500	75	31	9	49													Pin measured at 0.395 inch at 250 PSI
225	45	11.4	1475	75	31	9	48													
226	45	11.3	1400	75	31	9	49													
227	45	11.5	1350	100	31	9	49													
228	45	11.4	1350	100	31	9	49													
229	45	11.4	1325	90	32	9	49													
230	45	11.6	1300	90	32	9	50													
231	45	11.3	1350	90	31	10	50													
232	45	11.3	1375	100	31	10	49													
233	45	11.2	1400	90	31	10	50													
234	45	11.2	1475	100	31	10	50													
235	60	11.1	1500	100	31	10	49													
236	45	11.2	1400	100	31	10	50													
237	45	11.2	1425	100	31	10	49													
238	45	11.1	1450	100	31	10	50													Pin measured at 0.307 inch at 250 PSI
239	45	11.1	1450	100	31	10	50													
240	45	11.2	1450	100	31	11	51													
241	45	11.0	1450	100	31	11	51													
242	45	11.0	1500	100	31	11	49													
243	45	11.1	1425	100	31	11	51													
244	45	11.1	1450	100	31	11	51													
245	45	11.0	1500	100	31	11	51													
246	45	11.0	1475	100	31	11	51													
247	45	11.0	1475	100	31	11	50													
248	45	11.0	1425	100	31	11	51													
249	45	11.0	1500	100	31	11	50													
250	45	11.1	1450	100	31	11	50													Pin measured at 0.424 inch at 250 PSI
251	45	11.0	1450	125	31	11	50													
252	45	11.1	1350	125	31	11	50													
253	45	11.0	1325	125	31	11	52													
254	45	10.9	1325	125	32	11	52													
255	45	11.0	1325	125	31	11	52													
256	—	11.0	1425	100	32	10	49													
257	45	11.1	1400	100	32	10	50													Pin measured at 0.440 inch at 250 PSI
258	45	11.1	1475	100	32	10	50													
259	45	11.1	1440	100	32	10	51													
260	45	11.1	1500	100	32	10	50													Pin measured at 0.440 inch at 250 PSI
261	75	11.0	1450	100	32	10	51													
262	45	11.1	1450	100	32	9	48													
263	45	11.2	1425	90	32	9	49													
264	45	11.5	1450	75	31	7	49													
265	45	11.5	1400	75	31	8	49													
266	45	11.3	1475	75	31	9	50													
267	45	11.4	1450	75	32	8	51													
268	45	11.3	1475	75	32	8	50													
269	45	11.3	1475	75	32	9	50													
270	45	11.4	1450	80	32	9	51													
271	45	11.3	1475	90	32	8	50													
272	45	11.4	1350	75	32	8	51													
273	45	11.4	1325	90	32	9	51													

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10-4)		Flywheel revolutions	Temperatures												Remarks
								Rotor 1		Rotor 2		Rotor 3		Rotor 4		Piston housing		Pressure plate		
			Max	Min	Max	Min		Start	Max	Start	Max	Start	Max	Start	Max	Start	Max	Start	Max	
274	90	11.4	1425	75	32	8	52													
275	45	11.4	1400	80	32	8	50													
276	60	11.3	1440	75	31	9	50													Pin measured at 0.458 inch at 250 PSI
277	45	11.4	1425	75	32	9	49													
278	45	11.2	1500	100	32	10	49													
279	45	11.3	1450	100	32	10	50													
280	45	11.2	1450	100	32	10	49													
281	45	11.2	1400	100	32	10	50													
282	45	11.1	1425	100	32	10	49													
283	45	11.1	1500	100	32	10	50													
284	45	11.3	1450	100	32	10	49													
285	45	11.3	1450	100	32	10	50													Pin measured at 0.470 inch at 250 PSI
286	45	11.2	1400	100	32	9	50													
287	45	11.2	1450	90	32	9	50													
288	45	11.3	1400	90	32	9	50													
289	45	11.3	1425	75	32	9	49													
290	45	11.4	1450	90	32	9	48													
291	60	11.4	1450	75	32	9	50													Pin measured at 0.481 inch at 250 PSI
292	60	11.4	1425	75	31	9	48													
293	45	11.3	1400	75	32	9	49													
294	45	11.4	1425	75	32	9	50													
295	45	11.3	1400	75	32	9	51													
296	45	11.2	1475	75	32	9	50													
297	60	11.2	1475	75	32	9	50													
298	45	11.3	1425	75	32	9	51													
299	45	11.2	1400	75	32	9	49													
300	45	11.2	1425	80	32	9	50													
301	45	11.3	1475	100	32	8	50													
302	90	11.3	1425	80	32	9	49													Instrument air pressure was low
303	45	11.3	1425	75	32	9	50													
304	45	11.4	1450	100	32	9	50													
305	45	11.4	1425	75	32	9	49													
306	45	11.4	1450	75	31	9	49													
307	45	11.5	1400	75	31	9	50													
308	45	11.3	1450	75	31	9	48													
309	45	11.4	1500	75	31	9	50													
310	45	11.4	1425	75	31	9	49													
311	45	11.4	1450	75	31	9	49													Pin measured at 0.496 inch at 250 PSI
312	45	11.4	1450	75	31	9	49													
313	45	11.4	1450	75	31	9	50													
314	45	11.5	1450	75	31	9	49													
315	45	11.5	1425	75	31	9	50													
316	45	11.4	1450	80	32	9	50													
317	45	11.4	1450	80	31	9	51													
318	45	11.5	1475	80	32	8	50													
319	45	11.3	1450	75	32	9	50													
320	45	11.4	1450	90	32	9	50													
321	60	11.3	1450	90	32	9	53													Pin measured at 0.510 inch at 250 PSI
322	60	11.3	1425	80	32	9	50													
323	45	11.4	1450	75	32	7	50													
324	45	11.5	1450	75	32	7	51													
325	45	11.3	1500	90	32	8	51													
326	45	11.2	1425	100	33	9	52													
327	45	11.3	1450	90	32	8	51													
328	45	11.3	1475	90	32	9	51													

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Temperatures												Remarks
								Rotor 1		Rotor 2		Rotor 3		Rotor 4		Piston housing		Pressure plate		
			Max	Min	Max	Min		Start	Max	Start	Max	Start	Max	Start	Max	Start	Max	Start	Max	
329	45	11.3	1475	90	32	9	51													
330	60	—	1450	90	32	9	51													
331	45	—					51													
332	45	11.3	1450	100	32	9	50													
333	45	11.4	1425	100	32	9	51													
334	45	11.3	1450	100	32	8	51													
335	45	11.3	1500	100	32	9	50													
336	45	11.3	1450	75	31	9	50													
337	45	11.4	1450	75	31	9	49													
338	45	11.5	1525	100	32	10	51													
339	45	11.3	1500	100	32	10	50													
340	45	11.1	1500	100	32	10	52													
341	45	11.3	1525	100	32	10	51													Pin measured at 0.553 inch at 250 PSI
342	45	11.3	1525	100	32	10	51													
343	45	11.3	1550	100	32	11	51													
344	45	11.4	1550	100	32	11	51													
345	45	11.5	1550	100	32	10	52													
346	45	11.4	1500	100	32	10	51													
347	45	11.4	1525	100	32	9	51													
348	60	11.2	1475	100	32	9	50													
349	45	11.2	1500	100	32	9	50													
350	45	11.3	1500	100	32	9	49													Pin measured at 0.555 inch at 250 PSI
351	75	11.4	1475	100	32	9	49													
352	45	11.4	1500	75	33	9	50													
353	45	11.4	1525	100	33	9	51													
354	45	11.2	1500	100	33	9	51													
355	60	11.3	1500	100	33	9	52													
356	50	11.3	1625	100	33	8	51													
357	45	11.2	1575	100	33	8	55													
358	45	11.5	1550	100	33	8	53													
359	45	11.3	1550	100	33	8	52													
360	45	1.5	1575	100	33	8	51													
361	45	11.3	1575	100	33	8	53													
362	45	11.6	1575	75	33	8	52													
363	45	11.3	1575	75	33	8	51													
364	45	11.5	1550	75	33	8	53													
365	45	11.4	1575	75	33	8	52													
366	55	11.4	1575	75	33	8	51													
367	45	11.6	1525	75	32	8	52													
368	45	11.6	1550	75	32	8	53													
369	45	11.6	1550	75	32	8	53													
370	45	11.6	1550	75	32	8	55													
371	45	11.7	1550	75	32	8	53													
372	45	11.7	1525	75	32	8	52													
373	45	11.7	1550	75	32	8	53													
374	45	11.6	1550	75	32	8	53													
375	45	11.7	1550	75	32	8	52													
376	45	11.7	1575	75	32	8	53													Pin measured at 0.595 inch at 250 PSI
377	60	11.8	1550	75	32	8	53													
378	45	11.4	1600	75	32	8	51													
379	45	11.5	1650	75	32	8	51													
380	60	11.5	1650	75	33	8	52													
381	60	11.4	1550	75	32	8	52													Pin measured at 0.617 inch at 250 PSI
382	75	11.4	1625	75	33	8	51													
383	45	11.4	1600	75	33	8	50													

Event number	Time between stops (minutes)	Stop time (seconds)	Brake pressure (PSI)		Torque (lbs x 10^{-4})		Flywheel revolutions	Temperatures												Remarks
								Rotor 1		Rotor 2		Rotor 3		Rotor 4		Piston housing		Pressure plate		
			Max	Min	Max	Min		Start	Max	Start	Max	Start	Max	Start	Max	Start	Max	Start	Max	
384	60	11.5	1600	75	33	8	52													
385	45	11.3	1625	100	33	8	51													
386	45	11.3	1575	75	33	8	52													
387	45	11.3	1625	75	33	8	52													
388	45	11.3	1625	75	33	8	51													
389	45	11.4	1650	75	33	8	50													
390	45	11.4	1625	75	33	8	51													
391	45	11.5	1700	75	33	8	50													
392	45	11.5	1575	75	33	8	52													
393	45	11.3	1550	75	33	8	52													
394	45	11.5	1675	75	32	8	50													
395	45	11.5	1575	75	32	8	51													
396	45	11.5	1625	75	32	8	51													Pin measured at 0.630 inch at 250 PSI
397	45	11.6	1600	75	32	8	50													
398	45	11.6	1600	75	32	8	51													
399	45	11.4	1575	75	32	8	51													
400	45	11.3	1600	75	32	8	52													
401	45	11.3	1600	75	32	8	52													
402	45	11.3	1600	75	32	8	52													
403	45	11.6	1600	75	32	8	52													
404	45	11.8	1625	75	32	8	52													
405	45	11.7	1625	75	32	8	52													Pin measured at 0.654 inch at 250 PSI
406	75	11.0	1600	120	31	10	50													
407	45	11.0	1620	125	31	10	51													
408	45	11.1	1610	125	31	10	52													
409	45	11.0	1650	120	31	10	50													
410	45	11.0	1625	120	31	10	50													
411	60	11.2	1675	120	31	10	51													
412	45	11.1	1625	110	31	10	51													
413	45	11.1	1625	130	31	10	53													
414	45	11.3	1600	120	31	10	52													
415	45	11.3	1650	120	31	10	52													Pin measured at 0.658 inch at 250 PSI
416	50	11.3	1700	120	31	10	52													
417	45	11.1	1750	120	31	10	52													
418	45	11.2	1700	120	31	10	53													
419	45	11.0	1675	120	31	10	53													
420	45	11.1	1675	120	31	10	52													
421	90	11.0	1700	120	31	10	53													
422	45	11.1	1725	120	31	10	53													
423	45	11.0	1675	120	31	10	52													
424	45	11.2	1750	120	31	10	54													
425	45	11.0	1700	120	31	10	52													
426	45	11.1	1725	125	31	10	51													
427	45	11.1	1750	125	31	10	52													
428	205	9.9	800	250	14	9	81													Pin measured at 0.676 inch at 250 PSI
429	80	9.9	800	240	14	9	77													Pin measured at 0.678 inch at 250 PSI. Test terminated because of torque decrease.

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13. ABSTRACT

7/10

This report presents the results of a comparison test between a conventional B-52 disk brake and a newly developed sintered metal brake. The conventional B-52 brake, with cerametallic linings, is currently used on the B-52 aircraft and on the BAK-9 and BAK-12 aircraft arresting systems. The newly developed brake has sintered metal brake linings and is designed for the same applications as the conventional brake.

The objective of the test program was to compare the useful life and operating characteristics of the conventional brake with that of the sintered metal brake under conditions of simulated arrestments. The laboratory controlled conditions simulated a BAK-12 arrestment of a 35,000-pound aircraft at a speed of 150 knots.

The conventional brake yielded a useful life of 166 arrestments and the sintered metal brake had a life of 427 arrestments. The coefficients of friction for both brakes remained relatively constant throughout the test program.

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	ROLE	WT	ROLE	WT	ROLE	WT
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